Technical Report Documentation Page

1. Report No.	2. Government Accession No.	3. Recipient's Catalog No.
SWUTC/96/467106-1		

4. Title and Subtitle	5. Report Date
Measures of Effectiveness for Major Investment Studies **(Online Version 2.0, February 1997)**	November 1996
	6. Performing Organization Code
7. Author(s) Shawn M. Turner, Matthew E. Best, and David L. Schrank	8. Performing Organization Report No. Research Report 467106-1
9. Performing Organization Name and Address Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	10. Work Unit No. (TRAIS)
	11. Contract or Grant No. 10727
12. Sponsoring Agency Name and Address Southwest Region University Transportation Center Texas Transportation Institute The Texas A&M University System College Station, Texas 77843-3135	13. Type of Report and Period Covered
	14. Sponsoring Agency Code

15. Supplementary Notes

Supported by general revenues from the State of Texas.

16. Abstract

This report examines measures of effectiveness that can be used to compare the benefits and impacts of transportation improvements for a major investment study. A literature review was used to gather information about transportation performance measures and the social, economic and environmental effects of transportation. All metropolitan planning organizations within the state of Texas were surveyed to determine the state-of-the-practice for major investment studies within the state. A list of candidate measures of effectiveness for major investment studies was developed, and various judging criteria were used to qualitatively evaluate the measures.

Preferred measures of effectiveness were identified that quantify the following benefits or impacts of transportation improvements: transportation performance, financial/economic performance, social impacts, land use/economic development impacts, and environmental impacts. Preferred transportation performance measures consisted mainly of person movement and travel time-based measures. Financial/economic performance measures centered around the cost effectiveness (benefit-to-cost ratio) and the financial feasibility, and considered the full costs (including externalities, or cost not borne by motorists) of transportation. Social, land use/economic development, and environmental impacts were identified, and coincided with those concerns most often expressed by citizen or community advocacy groups. Findings from the study illustrated the importance of matching the appropriate evaluation measures to the goals and objectives set forth early in the major investment study process.

17. Key Words	18. Distribution Statement
major investment studies, multimodal planning, measures of effectiveness, transportation investments, alternatives analysis	No restrictions. This document is available to the public through NTIS: National Technical Information Service 5285 Port Royal Road Springfield, Virginia 22161

19. Security Classif.(of this report)	20. Security Classif.(of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified	96	

Form DOT F 1700.7 **(8-72)** **Reproduction of completed page authorized**

This page intentionally left blank.

MEASURES OF EFFECTIVENESS FOR MAJOR INVESTMENT STUDIES

by

Shawn M. Turner
Assistant Research Scientist

Matthew E. Best
Graduate Research Assistant

and

David L. Schrank
Assistant Research Scientist

Research Report 467106-1

Sponsored by

The State of Texas
Southwest Region University Transportation Center
Texas Transportation Institute
The Texas A&M University System
College Station, Texas 77843-3135

November 1996

This page intentionally left blank.

ABSTRACT

This report examines measures of effectiveness that can be used to compare the benefits and impacts of transportation improvements for a major investment study. A literature review was used to gather information about transportation performance measures and the social, economic and environmental effects of transportation. All metropolitan planning organizations within the state of Texas were surveyed to determine the state-of-the-practice for major investment studies within the state. A list of candidate measures of effectiveness for major investment studies was developed, and various judging criteria were used to qualitatively evaluate the measures.

Preferred measures of effectiveness were identified that quantify the following benefits or impacts of transportation improvements: transportation performance, financial/economic performance, social impacts, land use/economic development impacts, and environmental impacts. Preferred transportation performance measures consisted mainly of person movement and travel time-based measures. Financial/economic performance measures centered around the cost effectiveness (benefit-to-cost ratio) and the financial feasibility, and considered the full costs (including externalities, or cost not borne by motorists) of transportation. Social, land use/economic development, and environmental impacts were identified, and coincided with those concerns most often expressed by citizen or community advocacy groups. Findings from the study illustrated the importance of matching the appropriate evaluation measures to the goals and objectives set forth early in the major investment study process.

DISCLAIMER

ACKNOWLEDGMENT

This publication was developed as part of the University Transportation Centers Program which is funded 50% with general revenue funds from the State of Texas.

The authors would like to thank the following persons for their comments on a draft of the final document:

- John Brunk, Texas Transportation Institute-Arlington;
- Tim Lomax, Texas Transportation Institute;
- Glenn McVey, Texas Department of Transportation-Austin; and,
- Dennis Perkinson, Texas Transportation Institute.

EXECUTIVE SUMMARY

Introduction

Metropolitan transportation planning rules and regulations were issued by the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) in October 1993 (1) in direct response to the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. These regulations prescribe the use of major investment studies (MIS) as an element of the metropolitan transportation planning process. The primary objective of a MIS is to support decisions on significant transportation investments. A MIS accomplishes this goal by developing information about the impacts or likely consequences of alternative transportation strategies at the corridor or subarea level. The alternative strategies in a MIS typically include several of the following alternatives:

- No Build;
- Transportation System Management(TSM)/Transportation Demand Management (TDM) Strategies;
- High-Occupancy Vehicle (HOV) and Transit Service Strategies;
- Addition of HOV and Single-Occupancy Vehicle (SOV) Capacity;
- Addition of SOV Capacity; and,
- Rail Transit.

Federal guidance (2) indicates that a MIS should include information about the following impacts for each transportation alternative: economic, social, environmental, safety, operating efficiencies, land use and economic development, financing, and energy consumption. The metropolitan transportation planning regulations issued in October 1993 issue basic requirements and elements to be satisfied by a MIS.

Because MIS procedures are relatively new to the metropolitan transportation planning process, many urban areas are dealing with complex issues of multimodal comparisons and analyses. The FHWA and FTA will be issuing non-regulatory guidance for use in conducting a MIS, and plan on issuing additional technical guidance to assist urban areas in meeting MIS requirements. The National Transit Institute at Rutgers University also has initiated a training course (3) that has been offered at several locations in the United States.

Problem Statement

Major investment studies are now required for any major metropolitan transportation investment. The primary objective of a MIS is to support decisions on significant transportation investments, and ensure that all modal alternatives are considered in the early stages of transportation planning analyses. There has been limited guidance for selection of measures of effectiveness (MOEs) in comparing alternatives in the MIS process, even though MOEs play a key role in selecting the transportation alternative(s) that is carried through to further planning stages.

Study Objectives and Scope

The goal of this study was to identify current practices in comparison of multimodal alternatives, and develop guidelines for the selection of appropriate multimodal measures for use in a MIS. The research team surveyed MPOs and other transportation agencies in the state of Texas to determine state-of-the-practice in multimodal analyses. The researchers identified various MOEs and their success in multimodal alternative comparisons, and developed guidelines for selecting MOEs for use in a MIS.

Findings

A review of the literature indicated that many commonly used measures can be applied to multimodal situations. Such measures as person miles of travel, travel time, and benefit-to-cost ratio are applicable across modes and can be used directly in many of the decision making approaches discussed in the proceeding paragraph. With an increase in emphasis on environmental and social impacts of transportation, such measures as energy consumption, air pollution emissions, and number of displaced homes and businesses have been cited as appropriate measures. In total cost-benefit analysis, these same measures can be converted into monetary terms.

A state-of-the-practice review of major investment studies within the state of Texas revealed that 20 studies have been completed, are underway, or are in the early scoping stages. The review found that the emphasis and content of the major investment studies varied between regions. The state-of-the-practice review also found many examples of multimodal measures being used to compare transportation alternatives.

The research team performed a qualitative assessment of the various measures using the following criteria:

- Applicability to Individual and Aggregate Transportation Modes;
- Ease of Measure Calculation and Analyses;
- Accuracy of Measure Results;
- Clear and Consistent Interpretation of Results; and,
- Clarity and Simplicity.

The resulting preferred measures of effectiveness are contained in Table S-1.

The preferred transportation performance MOEs are predominantly related to persons and time. The focus on persons and time matches the focus of transportation engineering, which is the " . . . <u>safe</u> and <u>efficient</u> movement of <u>people</u> and <u>goods</u>." These person movement and time-related measures quantify the impacts and effectiveness of a wide range of transportation alternatives.

The preferred MOEs for estimating the financial/economic performance are the benefit-to-cost (b/c) ratio (using the "full" or total transportation costs), financial feasibility, and equity. Total cost analyses used to generate these measures account for transportation externalities and other costs that typically are not payed directly for the construction of a transportation improvement.

The preferred MOEs for assessing the social impact of transportation projects include the number of displaced persons and homes, neighborhood cohesion (traffic through neighborhoods), and the accessibility to community services. These measures are primarily quantitative, and the values represent actual calculated numbers. Public or community perception may be used as a qualitative measure of a project's social impact.

The preferred MOEs for the land use/economic development impact are the number of displaced businesses and the accessibility to employment and future development sites. These measures assess the relation of the proposed transportation project to current and projected land uses in the corridor.

The preferred MOEs for assessing the environmental impacts include energy/fuel consumption, mobile source emissions, noise levels, and visual/aesthetic quality. These measures could be used in either an Option I or Option II MIS. Impacts that must be considered in an Option II MIS, where an EIS is part of the MIS process, include vibration, water resources, wildlife/vegetative habitat, parkland/open/green space, cultural resources, agriculture/forest resources, geologic resources, and hazardous wastes.

The study also found several significant factors that should be considered when selecting measures of effectiveness for a major investment study:

- Match the MOEs with the goals and objectives of the MIS;
- Develop and select the MOEs early in the study with key input from local decision-makers;
- Use a comprehensive set of measures, but do not substantially duplicate or restate benefits or impacts;
- When possible, quantify impacts and don't simply use subjective judgment;
- Provide perspective on the magnitude of the impacts; and,
- Identify the error levels of calculations in relation to the measure values.

Table S-1. Preferred Measures for Evaluating the Performance and Impact of Transportation Improvements

Transportation Performance • average travel time • total delay (vehicle, person or ton-hours) • average travel rate • person-miles of travel (PMT), or PMT in congested ranges • person movement • person-hours of travel (PHT), or PHT in congested ranges • person movement speed • accident reduction
Financial/Economic Performance • benefit-to-cost ratio (using total or full cost analysis) • financial feasibility • cost per new person-trip
Social Impacts • number of displaced persons • number and value of displaced homes • accessibility to community services • neighborhood cohesion
Land Use/Economic Development Impacts • number and value of displaced businesses • accessibility to employment • accessibility to retail shopping • accessibility to new/planned development sites
Environmental Impacts • noise levels (dB) • mobile source emissions (NO_x, HC, CO, and PM-10) • energy consumption • visual quality/aesthetics • water resources (Option II MIS only) • wildlife/vegetative habitat (Option II MIS only) • parkland/open/green space (Option II MIS only) • agriculture/forest resources (Option II MIS only) • cultural resources (Option II MIS only) • geologic resources (Option II MIS only) • hazardous wastes (Option II MIS only) • vibration (Option II MIS only)

Conclusions

The selection of MOEs is a critical element of the major investment study. The measures selected to evaluate alternative transportation improvements determine what information is provided to decision-makers and seriously affects the conclusions of the study. Smaller MISs investigated in this study often did not include a sufficient range of MOEs, leading to decisions based on incomplete evidence. With full information provided by a complete range of MOEs, a completely informed decision can be incorporated into a MIS.

Table S-1 lists MOEs that are ideally suited to multimodal transportation analyses. The designation of "preferred MOEs" in this table reflects the results of a qualitative assessment and state-of-the-practice review of MISs in Texas. Transportation performance measures that were most frequently cited in the literature and state-of-the-practice reviews include time and person-based measures. Both are relatively easy to calculate with field observations or to estimate with computer models. Vehicle-based MOEs are often easier to calculate and estimate, but have modal biases which are corrected with the use of person-based MOEs.

The economic, social, land use, and environmental impacts of transportation improvements cannot be ignored. These issues are often complicated and their impacts can be difficult to quantify. The importance of providing as much information regarding these impacts as possible should be tempered by the cost of quantifying these impacts. The MOEs cited in Table S-1 are easily quantifiable and cover a range of impacts that is sufficient for most MISs. However, it is important to realize that individual MISs may have different considerations, and impacts not quantified by the MOEs in Table S-1 may need to be highlighted in the analysis.

Recommendations

Selection of MOEs for inclusion in a MIS should be undertaken very carefully. The MOEs need to blend the concerns of the technical practitioners with those of the general public. Generally, those performing a MIS are more concerned with the effects on the transportation system and the costs of the improvement project, while the general public is also interested in the social and environmental impacts of alternatives. The needs of both must be addressed. It is recommended that a wide range of both technical MOEs and social/environmental MOEs be selected to address the concerns of all participants.

The MOEs recommended in Table S-1 are not meant to serve as a "cookbook" for all major investment studies. Each MIS will be unique. Different corridors in different cities may have differing concerns which need to be addressed. A MIS in Galveston would require the consideration of effects on wetlands and storm water management. These considerations, however, might be unimportant in El Paso. This research is meant to serve as a guide, presenting a base of MOEs which would be useful in almost any MIS. Concerns of individual cities and corridors should be included, and MOEs measuring impacts related to these concerns developed and included in a MIS.

This page intentionally left blank.

TABLE OF CONTENTS

LIST OF FIGURES

Page

LIST OF TABLES

Page

This page intentionally left blank.

LIST OF ACRONYMS USED IN THIS DOCUMENT

AADT	average annual daily traffic
ADT	average daily traffic
AWT	average weekday traffic
CMS	congestion management system
DOT	department of transportation
EA	environmental assessment
EIS	environmental impact statement
EPA	Environmental Protection Agency
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
HOV	high-occupancy vehicle
IH	Interstate Highway
ISTEA	Intermodal Surface Transportation Efficiency Act
LOS	level of service
MIS	major investment study
MOE	measure of effectiveness
MPO	metropolitan planning organization
MTP	metropolitan transportation plan
NCHRP	National Cooperative Highway Research Program
NEPA	National Environmental Policy Act
NHS	National Highway System
PHT	person-hours of travel
PMT	person-miles of travel
SOV	single-occupant vehicle
SPASM	Sketch Planning Analysis Spreadsheet Model
STIP	statewide transportation improvement program
TDM	transportation demand management
TSM	transportation systems management
TIP	transportation improvement plan
VHT	vehicle-hours of travel
VMT	vehicle-miles of travel

This page intentionally left blank.

CHAPTER I. INTRODUCTION

Metropolitan transportation planning rules and regulations were issued by the Federal Highway Administration (FHWA) and the Federal Transit Administration (FTA) in October 1993 (1) in direct response to the Intermodal Surface Transportation Efficiency Act (ISTEA) of 1991. These regulations prescribe the use of major investment studies (MIS) as an element of the metropolitan transportation planning process. State departments of transportation (DOTs), metropolitan planning organizations (MPOs), transit agencies, FTA, and FHWA must work together in a cooperative and collaborative process when initiating and performing a MIS.

The primary objective of a MIS is to support decisions on significant transportation investments. A MIS accomplishes this goal by developing information about the impacts or likely consequences of alternative transportation strategies at the corridor or subarea level. The alternative strategies in a MIS typically include several of the following alternatives:

- No Build;
- Transportation System Management(TSM)/Transportation Demand Management (TDM) Strategies;
- High-Occupancy Vehicle (HOV) and Transit Service Strategies;
- Addition of HOV Capacity;
- Addition of Single Occupancy Vehicle (SOV) Capacity;
- Rail Transit; and,
- Combinations of the above.

Federal guidance (2) indicates that a MIS should include information about the following impacts for each transportation alternative: economic, social, environmental, safety, operating efficiencies, land use and economic development, financing, and energy consumption. The metropolitan transportation planning regulations issued in October 1993 mandate basic requirements and elements to be satisfied by a MIS.

Because MIS procedures are relatively new to the metropolitan transportation planning process, many urban areas are dealing with complex issues of multimodal comparisons and analyses. The FHWA and FTA will be issuing non-regulatory guidance for use in conducting a MIS, and plan on issuing additional technical guidance to assist urban areas in meeting MIS requirements. The National Transit Institute at Rutgers University also has initiated a training course (3) that has been offered at several locations in the United States.

Problem Statement

Major investment studies are now required for any major metropolitan transportation investment. The primary objective of a MIS is to support decisions on significant transportation investments, and ensure that all modal alternatives are considered in the early stages of transportation planning analyses. There has been limited guidance for selection of measures of effectiveness (MOEs) in comparing alternatives in the MIS process, even though MOEs play a key role in selecting the transportation alternative(s) that is carried through to further planning stages.

Study Objectives and Scope

The goal of this study was to identify current practices in comparison of multimodal alternatives, and develop guidelines for the selection of appropriate multimodal measures for use in a MIS. The research team surveyed MPOs and other transportation agencies in the state of Texas to determine state-of-the-practice in multimodal analyses. The researchers identified various MOEs and their success in multimodal alternative comparisons, and developed guidelines for selecting MOEs for use in a MIS.

Organization of Report

This report is organized into four chapters:

Chapter One, Introduction, provided an introduction to the research topic and presents the research objectives and scope.

Chapter Two, Background, provides information about metropolitan planning requirements prescribed by ISTEA, in particular the conduct of a MIS. The chapter summarizes MIS guidance currently available from FHWA and FTA, and summarizes several examples of MIS processes that have been utilized by various transportation agencies across the U.S. This chapter also includes a summary of the literature with regard to comparison of multimodal alternatives and the selection of MOEs.

Chapter Three, Findings, presents a summary of the state-of-the-practice review of all MISs being conducted in the state of Texas. The chapter also presents a description of candidate MOEs, and provides a qualitative assessment of the MOEs that can be or have been utilized in MISs.

Chapter Four, Conclusions and Recommendations, presents the conclusions of the study related to the preferred MOEs for use in a MIS. Recommended MOEs are suggested for different performance or impact categories. Guidance for selecting MOEs for a MIS is also provided.

CHAPTER II. BACKGROUND

This chapter provides a review of the literature on MISs and multimodal comparisons, and contains brief descriptions of six MIS examples taken from around the nation. The literature review is divided into three sections:

- Metropolitan Transportation Planning and Major Investment Studies;
- Major Investment Study Procedures; and
- Multimodal Alternative Evaluation and Comparisons.

The first section summarizes the FHWA/FTA Final Rule on Metropolitan Transportation Planning. The major steps in the transportation planning process are summarized and the role of MISs in the process is highlighted. The second section discusses MIS procedures. Included are discussions of process organization, alternatives development, alternatives evaluation, and integration of the MIS process with the National Environmental Policy Act (NEPA) process. The final section of the literature review presents past research on multimodal alternative evaluations and comparisons. Several methods of comparing multimodal alternatives are presented along with suggestions of evaluation criteria and specific MOEs.

The section entitled "MIS Case Study Examples" summarizes examples of MISs from around the United States. Included in this section are MIS examples from the following areas:

- US 301 South Corridor Study, Maryland;
- Miami East-West Multimodal Corridor Study, Florida;
- Central County Corridor Study, Orange County, California;
- Pocatello/Chubbuck Corridor Study, Idaho;
- Oklahoma State Highway 152 Corridor Study, Oklahoma City, Oklahoma; and,
- IH-435 Major Investment Study, Kansas City, Missouri.

Metropolitan Transportation Planning and Major Investment Studies

The Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA) mandated the reorganization of the metropolitan transportation planning process. ISTEA requires a comprehensive and continuous transportation planing process, developed and implemented cooperatively with all appropriate agencies. On October 28, 1993, the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) established metropolitan transportation planning regulations (1) to implement the mandates of ISTEA.

The FHWA/FTA regulations created a structure to ensure comprehensive, continuing and cooperative metropolitan planning with an increased role of the Metropolitan Planning Organization

(MPO) (see Figure 1). The MPO is responsible for carrying out the coordinated metropolitan planning process in a metropolitan planning area. The MPOs are directed to develop unified planning work programs that describe the planning priorities for a metropolitan planning area and all metropolitan transportation and transportation-related air quality planning. This includes provisions for corridor and subarea studies, or MISs. The final products of the metropolitan planning process are the Metropolitan Transportation Plan (MTP) and the Transportation Improvement Program (TIP). The metropolitan area TIPs are incorporated into the Statewide Transportation Improvement Program (STIP), which is submitted to the FHWA and the FTA for joint approval.

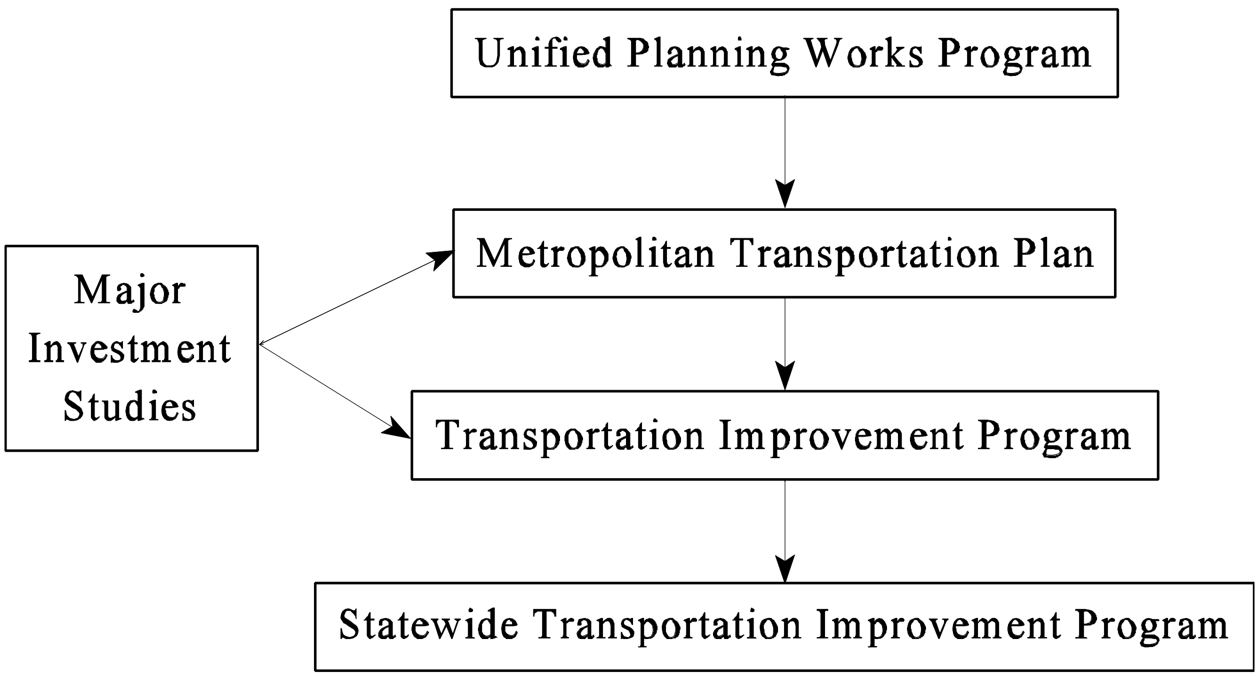

Figure 1. Metropolitan Transportation Planning Process.

The FHWA/FTA regulations have outlined fifteen basic planning elements which must be taken into account in the transportation planning process in metropolitan areas. These elements are listed in Table 1. The FHWA/FTA regulations also contained additional stipulations, which are discussed in the following paragraphs.

The metropolitan transportation planning process shall include:

- A proactive public involvement process that provides complete information, timely public notice, full public access to key decisions, and supports early and continuing involvement of the public in developing plans and TIPs.
- Ensure that no person shall, on the grounds of race, color, sex, national origin, or physical handicap, be excluded from participation in, be denied benefits of, or be otherwise subjected to discrimination under any program receiving federal assistance from the United State Department of Transportation (USDOT).
- Identify actions necessary to comply with the Americans With Disabilities Act of 1990 and USDOT regulations, "Transportation for Individuals with Disabilities."
- Provide for the involvement of traffic, ridesharing, parking, transportation safety and enforcement agencies; commuter rail operators; airport and port authorities; toll authorities; appropriate private transportation providers, and where appropriate, city officials.
- Provide for the involvement of local, state and federal environmental, resource and permit agencies as appropriate.

The MTP must include all transportation projects which are planned to be implemented within the horizon year, typically twenty years or greater. The MTP must be updated at least every five years in all metropolitan areas except those classified by the Environmental Protection Agency (EPA) as non-attainment. These areas must update their plan at least once every three years. The MTP may include only projects for which funding has been allocated or for which future funding sources have been identified.

The TIP includes all projects within a metropolitan area which will be implemented within at least a three-year period. It must include all projects listed by year of implementation with indication of their funding source(s). The funding source(s) must be either identified as committed or be accompanied by a strategy to ensure its availability. The TIP must be updated at least every two years and must be approved by the Governor of the State for inclusion in the STIP. The STIP must be jointly approved by the FHWA and FTA.

To assist an MPO in the development of the MTP and TIP, MISs are utilized to determine the appropriate improvements to be planned at the corridor or subarea level. A MIS can be conducted by the MPO, the state DOT, or a transit agency. The MIS must be conducted in cooperation with all affected agencies and include public involvement. The results of a MIS may be input into the MTP. Alternately, the MTP can stipulate the performance of a MIS to determine the nature of an improvement to be included in the TIP.

Table 1. Fifteen Planning Elements in the Metropolitan Planning Process (Adapted from Reference 1)

1. Preservation of existing transportation facilities and, where practical, ways to meet transportation needs by using existing transportation facilities more efficiently.
2. Consistency of transportation planning with applicable Federal, State, and local energy conservation programs, goals, and objectives.
3. The need to relieve congestion and prevent congestion from occurring where it does not yet occur including:
   (i) The consideration of congestion management strategies or actions which improve the mobility of people goods in all phases of the planning process; and
   (ii) In Transportation Management Areas (TMAs), a congestion management system that provides for effective management of new and existing transportation facilities through the use of travel demand reduction and operation management strategies shall be developed.
4. The likely effect of transportation policy decisions on land use and development and the consistency of transportation plans and programs with the provisions of all applicable short- and long-term land use and development plans.
5. Programming of expenditures for transportation enhancement activities.
6. The effects of all transportation projects to be undertaken within the metropolitan planning area, without regard to the source funding.
7. International border crossings and access to ports, airports, intermodal transportation facilities, major freight distribution routes, national parks, recreation areas, monuments and historic sites, and military installations.
8. Connectivity of roads within metropolitan planning areas with roads outside of those areas.
9. Transportation needs identified through the use of management systems.
10. Preservation of rights-of-way for construction of future transportation projects, including future transportation corridors.
11. Enhancement of the efficient movement of freight.
12. The use of life-cycle costs in the design and engineering of bridges, tunnels, or pavement.
13. The overall social, economic, energy, and environmental effects of transportation decisions.
14. Expansion, enhancement, and increased use of transit services.
15. Capital investments that would result in increased security in transit systems.

A major metropolitan transportation investment is defined as (1):

> *". . . a high-type highway or transit improvement of substantial cost that is expected to have a significant effect on capacity, traffic flow, level of service, or mode share at the transportation corridor or subarea scale.*"

Examples of major metropolitan transportation investments include construction, expansion, or capacity expansion of a partially access-controlled arterial, construction or expansion of an HOV facility, or extension or expansion of a fixed guideway transit system. When the needs for a major metropolitan transportation investment are identified and federal funds are potentially involved in the financing of the project, a MIS must be undertaken to identify the strategy or strategies best suited to the local, regional, and state goals for the corridor or subarea.

A MIS is meant to take into account all direct and indirect costs of many different alternatives. FHWA and FTA regulations stipulate that all reasonable alternatives should be included in a MIS (consistent with planning element 6 in Table 1). To compare these alternatives, an unbiased decision-making process must be included in the MIS which does not handicap any alternatives because of its mode. The decision-making process should include consideration of factors such as mobility improvements; social, economic, land use, and environmental effects; operating efficiency; and, energy consumption (consistent with planning element 13, Table 1).

The FHWA and FTA suggest a linking of a metropolitan planning area's congestion management system (CMS) with the MIS process (planning elements 3 and 9, Table 1). The CMS can define the problems in a corridor or subarea that need to be addressed. In this way, the CMS can be used to define the purpose and needs of a MIS. Also, the MIS can provide input into the CMS by assessing different congestion management strategies, making a separate CMS analysis unnecessary (4).

Major Investment Study Procedures

Process Organization

The MIS process is summarized in Figure 2. After the need for a major transportation investment in a corridor or subarea is identified and the limits of the corridor or subarea defined, the MIS process is initiated. A lead agency must be chosen to coordinate the efforts of a MIS. The lead agency can be any organization deemed acceptable by the other involved agencies. These can include MPOs, state DOTs, transit operators, commuter rail and railroad agencies, transportation authorities, and city and county governments (3).

An important early step in the development of a MIS is to define the problems that exist in the corridor/subarea that will be studied. The clear definition of the transportation problems in a corridor/subarea will lead to a statement of the purpose and need of a MIS. The definition will allow for the identification and refinement of reasonable alternatives, information needs and evaluation measures.

Public involvement is an important element of a MIS. The public involvement process as described by the FHWA/FTA regulations is required for MISs. "*A reasonable opportunity . . . shall be provided for citizens and interested parties . . . to participate in the cooperative (MIS) process.*" (1)

Alternatives Development

The analysis of different transportation alternatives for improvements to a corridor or subarea is the heart of a MIS. The first step of this analysis is the definition of alternatives that will be considered for selection as the preferred alternative. As is the emphasis with most aspects of ISTEA, MISs are meant to be multimodal studies. With this requirement, different modal alternatives as well as multimodal alternatives must be included in a MIS whenever feasible. MIS alternatives must be developed in a well-documented, open process that includes provisions for public participation.

MIS alternatives are defined by their concept and scope. Details, such as mode or modes, general alignment, and length, which facilitate the comparison of performance and impacts of alternatives, are included in the definition of alternatives. Specific engineering details such as location of transit stations or specific right-of-way locations are usually unnecessary. Detail such as the number of stations or lanes may be necessary in estimating the capital costs of an alternative. Greater engineering detail will tend to complicate an analysis without providing any additional necessary information to decision-makers. Decisions based on concept and scope are appropriate for inclusion of an alternative in the MTP.

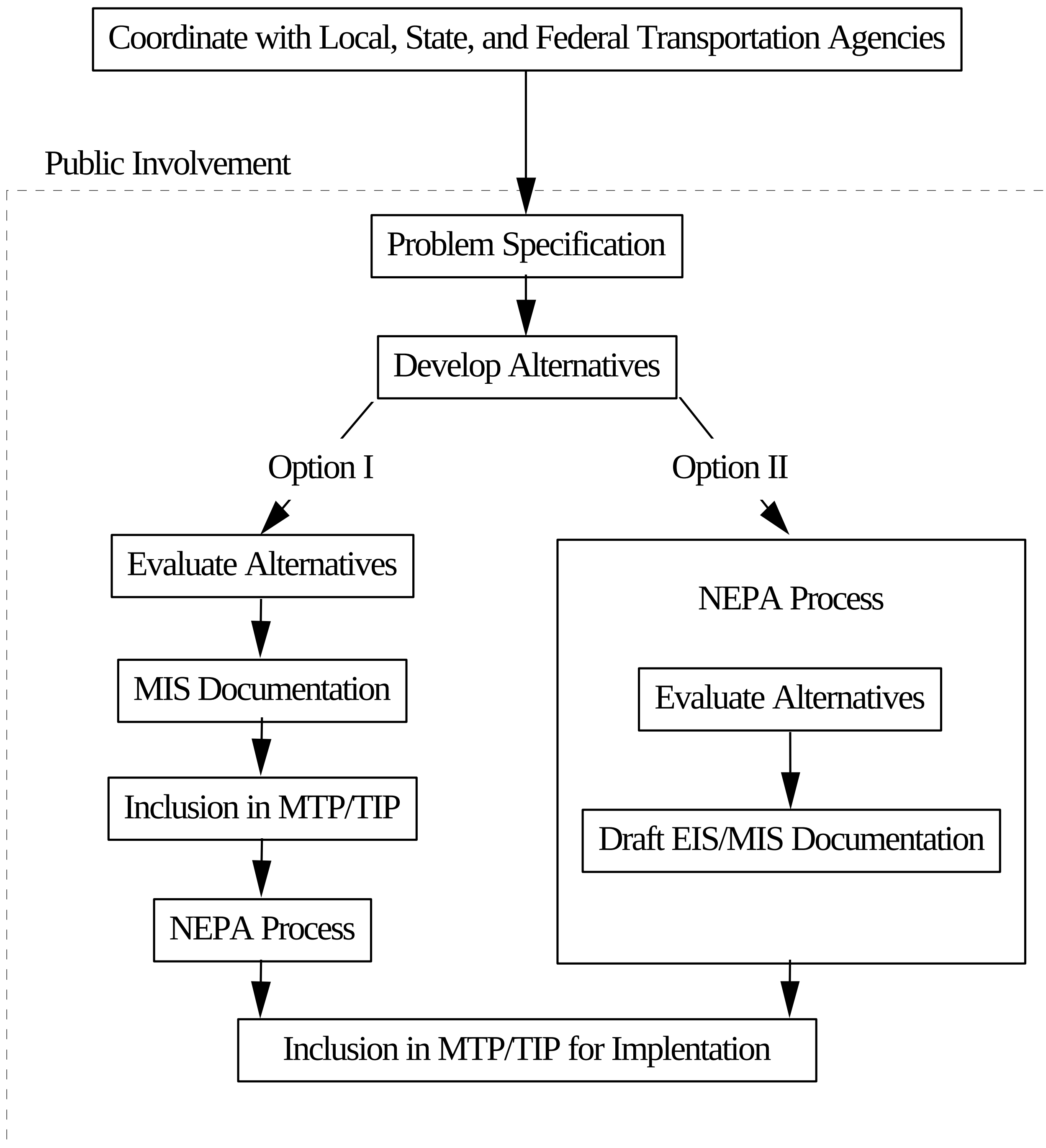

Figure 2. Major Investment Study Process

All transportation alternatives that have the chance of being selected as the locally preferred alternative should be included in a MIS without regard to its mode or cost. A MIS should provide information to decision makers to allow a timely and informed decision. By including competitive alternatives in the analysis, the decision maker's job will be made simpler and clearer. In practice, alternatives considered by most agencies to be non-competitive may be included to satisfy the comprehensiveness of the evaluation process.

MIS alternatives should (3):

- include baseline alternatives (no build, no build plus committed, or no build plus TSM/TDM);
- include all modes and alignments that have a good chance of becoming the locally preferred alternative;
- include alternatives that address different goals and objectives, and that respond to the needs of the corridor/subarea;
- cover a complete range of costs and benefits;
- include backup options for those that have questions regarding their feasibility; and
- be kept to a number which can be reasonably evaluated.

The third point, alternatives that address different goals and objectives, attempts to diversify alternatives. Alternatives developed in response to this point may include those that stress increases in capacity versus those that stress changes in land use and development versus those that stress mode shifts. The fourth point highlights a common problem of developing high cost, high benefit alternative and low cost, low benefit alternative without alternatives in an intermediate cost and benefit range.

The importance of the alternatives development stage of a MIS cannot be overstated. Without a full consideration of alternatives, it cannot be certain whether the locally preferred alternative is chosen. However, this is balanced with the need for economy and the lack of resources to evaluate every possible alternative solution for a corridor/subarea.

Evaluation of Alternatives

Once a set of alternatives is formed, they must be evaluated and compared to one another to determine which is the best solution for a particular corridor or subarea. The NEPA process has required the comparison of transportation alternatives to assess the environmental impacts of such improvements and the FTA has required that an alternatives analysis be preformed for capital transit improvements when federal funds are involved. Similarly, the MIS process requires the evaluation of alternatives to determine the most suitable improvement at the corridor or subarea scale. The FHWA/FTA regulations stipulate that " . . . *major investment studies shall evaluate the effectiveness and cost-effectiveness of alternative investments or strategies in attaining local, state and national goals and objectives*."

The *MIS Desk Reference* (5) suggests four evaluation perspectives that may be useful:

- effectiveness;
- cost-effectiveness;
- financial feasibility; and
- equity.

An evaluation of effectiveness answers the question: How well are concerns in the corridor addressed? Measures of effectiveness (MOEs) are meant to provide information regarding an alternative's effect on the defined transportation problems in the corridor (such as congestion or mobility), other effects of the improvement (such as development and land use effects), and negative impacts which act as constraints on the improvements (such as environmental concerns). The MOEs used in a MIS should reflect the following considerations (5):

- degree to which the problems are solved;
- early development through collaborative efforts;
- comprehensiveness in coverage, but no redundancy;
- quantification of impacts;
- provision of perspective on the magnitude of impacts;
- clearly defined levels of uncertainty; and
- allowance of cross modal comparisons (multimodal measures).

Cost-effectiveness analysis seeks to answer the question: Are the benefits from an improvement worth the costs of construction? This approach seeks to account for the total costs of an improvement (capital costs, operating costs, environmental costs, etc.) and the total benefits of an improvement (travel time savings, noise reduction, etc.). Previous and ongoing research is studying the application of cost-effectiveness measures in transportation; however, it is still difficult to quantify many of the costs and benefits that could improve the comprehensiveness of this type of analysis.

Financial feasibility analysis attempts to answer the following question: Will funds be available for implementation of an option? This evaluation method presents measures to estimate the impact on funding from existing and potential sources.

An equity analysis will answer the following question: Are costs and benefits distributed fairly across different population groups? It is important to assure that the quality of life of one group of citizens is not adversely impacted by improvements in another group's transportation system. It is also important to assure that different population groups receive similar levels of transportation services.

These evaluation techniques should be used together. Although different alternatives may respond better under different evaluation perspectives, the alternative that best balances these issues is likely to be the best solution to a corridor or subarea transportation need.

Integration of MIS and NEPA Process

The National Environmental Policy Act (NEPA) of 1969 mandated a process of environmental review for transportation projects. Public participation and the approval of the Federal Environmental Protection Agency (EPA) and state and local environmental agencies is required. The FHWA/FTA regulations suggest that participating agencies use the MIS as an input into an environmental impact statement (EIS) or environmental assessment (EA) or develop the MIS as a draft EIS or EA. These two options have been commonly referred to as NEPA Option I and NEPA Option II, or simply Option I and Option II.

Option I is described in the FHWA/FTA regulations as follows:

> *"As a minimum the participating agencies will use the major investment study as input to an environmental impact statement or environmental assessment prepared subsequent to the completion of the study. In such a case, the major investment study reports shall document the considerations given to alternatives and their impacts."*
> *(23 CFR 450.318, subpart F, paragraph 1)*

Several agencies have expressed concern about the legality of using a MIS as an input into the environmental review process (6). The determination of a locally preferred alternative using the MIS process, outside the NEPA process, may be a violation of NEPA. Environmental review agencies such as the EPA are less likely to be involved in a MIS and may not accept a locally preferred alternative that was not determined from an alternatives analysis within the NEPA framework.

Option II is described by the FHWA/FTA regulations as follows:

> *"The participating agencies may elect to develop a draft environmental impact statement or environmental assessment as part of the major investment study. At any time after the completion of the study and the inclusion of the major transportation investments in the plan and the TIP the participating agencies may request the development of final environmental decision documents required under NEPA for such major transportation investments, culminating in the execution of a Record of Decision or Finding of No Significant Impact by the FHWA and/or FTA."*
> *(23 CFR 450.318, subpart F, paragraph 2)*

Concerns have also been raised concerning Option II (6). The MIS process involves the analysis of alternatives defined by their concept and scope. The NEPA process requires a higher level of engineering detail to determine as accurately as possible the true environmental impacts of alternatives. To include the number of alternatives in the NEPA review process that would normally be included in a MIS analysis would be cumbersome. The timing of a MIS and NEPA review would also differ. The results of a MIS are to be included in the MTP and TIP while the NEPA process is normally performed closer to implementation of the project. By creating a MIS within the framework of the NEPA process, the potential exists for the extension of the NEPA process over a long period of time leading to delays in updating the plan and TIP and eventual implementation of the improvement.

The *MIS Desk Reference* (5) states the opinion that the level of detail in a MIS would be the same regardless of the choice of Option I or Option II for NEPA process integration. The opinion stated is that the only difference in MIS analysis is the method of reporting. An Option I MIS reports findings in a MIS report while an Option II MIS reports findings in a draft EIS or EA.

> *"The choice between Option I and Option II will depend on the desired timing of the implementation of the transportation solution, funding availability, the priority of the study in relation to others in the region, and the overall complexity of the alternatives selected for study."* (5)

The differences between Option I and Option II is an issue of great debate among transportation planners. Further clarification from the FHWA and FTA or a legal dispute with the EPA may be necessary to clarify these legal issues.

Multimodal Alternative Evaluation and Comparisons

The evaluation of different alternative transportation corridor improvements is the purpose of a MIS. By highlighting the differences between alternative courses of action, informed decisions are facilitated and an appropriate option is chosen. MOEs are used to determine how well a particular goal has been attained by a transportation improvement.

MOEs used to analyze alternative transportation projects for a corridor have traditionally been mode-specific. Highway alternatives have been compared to highway alternatives, and transit alternatives have been compared to other transit alternatives. ISTEA requires a multimodal approach to the transportation planning process, indicating the need for multimodal MOEs to compare alternatives in MISs.

Pre-ISTEA Methodologies

Cohen, Stowers, and Petersilia (7) developed an evaluation framework which reflects the following principles:

- Evaluation should be based upon careful examination of the range of decisions to be made and the issues of important considerations in making these decisions;
- Evaluation should guide the generation and refinement of alternatives, as well as the choice of a course of action;
- Evaluation should use qualitative as well as quantitative information;

- Evaluation should document uncertainties or value-laden assumptions if they might have an effect on key decisions;
- Evaluation should report all important likely consequences of choosing a course of action; and,
- Evaluation should provide information in a clear and concise manner.

Cohen et.al. (7) assert that " . . . *the information required by decision-makers cannot be reduced to a single measure or . . . a relatively small set of quantitative measures of alternatives and their consequences.*" The following components were identified as important elements to consider when evaluating system alternatives:

- Impact Assessment--Have important differences between alternatives been highlighted?
- Equity--Are costs borne by members of society commiserate with the benefits which they receive?
- Economic Efficiency--Are the benefits received from improvements sufficient to justify its costs?
- Adequacy of the Range of Alternatives Studied--Have all feasible alternatives been considered?
- Financial Feasibility--Will funds be available to implement alternatives on schedule?
- Legal and Administrative Feasibility--What adjustment would be necessary to existing laws and administrative guidelines to allow implementation of alternatives?
- Sensitivity of Finding to Uncertainties and Value-Laden Assumptions--Do uncertainties lead to difficulties for decision-makers to make informed decisions?

An FHWA study performed by Abrams and DiRenzo (8) investigated MOEs for comparing multimodal transportation systems management (TSM) strategies. Table 2 lists MOEs that were recommended in this study. Recognizing the size of this list, the authors suggested a set of MOEs that are most commonly used for TSM comparisons:

- point-to-point travel time;
- traffic volumes;
- vehicle delay;
- number of vehicles by occupancy;
- vehicle-miles of travel (VMT);
- vehicle-hours of travel (VHT);
- person-miles of travel (PMT);
- person-hours of travel (PHT);
- transit passengers;
- transit passenger-miles of travel;
- energy consumption; and
- air pollution emissions.

Table 2. Recommended MOEs for Various Objectives (Adapted from Reference 8)

Objective: Minimize Travel Time
- Person-Hours of Travel
- Point-to-Point Travel Time
- Response Time for Dial-a-Ride Transit
- Vehicle Delay
- Vehicle-Hours of Travel
- Vehicle Stops

Objective: Minimize Travel Costs
- Parking Cost
- Point-to-Point Out-of-Pocket Travel Costs
- Point-to-Point Transit Fares

Objective: Maximize Safety
- Accidents
- Accident Rate
- Freeway Incident Rate
- Traffic Violations

Objective: Maximize Security
- Crimes

Objective: Maximize Comfort and Convenience
- Active Revenue Vehicles with Working A/C & Heat
- Frequency of Transit Service
- Hours of Transit Operations
- Parking Accumulation
- Comfort & Convenience
- Transfers per Transit Passenger
- Transit Load Factor
- Transit Transfer Time
- Trip Distance
- Walking Distance from Parking Location to Dest.

Objective: Maximize Reliability
- Freeway Incident Delay
- Perceived Reliability of Service
- Schedule Adherence
- Variance of Average Point-to-Point Travel Time

Objective: Minimize Auto Usage
- Intersection Vehicle Turning Movements
- Number of Car Pools
- Number of Vehicles by Occupancy
- Person-Miles of Travel
- Person Trips
- Traffic Volume
- Vehicle-Miles of Travel

Objective: Maximize Transit Usage
- Information Requests
- Passenger-Miles of Travel
- Transit Passenger

Objective: Maximize Pedestrian and Bicycle Travel
- Bicycle Counts
- Pedestrian Counts

Objective: Maximize Capacity
- Critical Lane Volume
- Level of Service
- Parking Supply
- Volume/Capacity Ratio

Objective: Maximize Productivity
- Active Revenue Vehicles
- Inspection & Maintenance Cost per Labor Hour
- Length of Queue
- Operating Cost per Passenger Trip
- Operating Cost per Revenue Vehicle-Mile
- Operating Revenue/Operating Costs
- Passengers per Revenue Vehicle-Hour
- Passengers per Revenue Vehicle-Mile
- Revenue Vehicle-Miles per Active Revenue Vehicle

Objective: Minimize Operating Costs
- Operating and Maintenance Costs
- Operating Deficits
- Operating Revenue

Objective: Minimize Capital Costs
- Capital Costs

Objective: Minimize Noise Impacts
- Noise Levels

Objective: Minimize Air Pollution
- Concentration of Pollutants
- Tons of Emissions

Objective: Minimize Energy Consumption
- Energy Consumption

Objective: Maximize Transportation Disadvantaged Ridership

Transportation Disadvantaged Ridership

Objective: Minimize Economic Impacts
- Dollar Sales
- Employment

Objective: Maximize Equity
- Point-to-Point Travel Costs to Major Activity Centers
- Point-to-Point Travel Time to Major Activity Centers
- Population within 1/4 mile of Bus Route

Objective: Minimize Displacement
- Acres of Land Acquired
- Structures Displaced

Stuart and Weber (9) suggested the use of a goal-achievement methodology for comparing a large number of multimodal alternatives. In other words, alternatives are contrasted to one another by comparison of how well each achieves a defined goal for the transportation improvement. Goals, objectives and evaluation measures from a case study examining the Los Angeles/San Diego intercity corridor are listed in Table 3.

Walbridge (10) developed a methodology similar to a goal-achievement analysis. Transportation technologies are identified which best suit transportation needs. Transportation needs are defined by the following six characteristics:

- distribution of demand;
- dimension;
- flow;
- control;
- way; and,
- privacy.

When a transportation need is identified and defined by the six characteristics listed above, it is matched with the transportation technology which best suits it. It is noted that not all combinations of characteristics had a suitable transportation technology that would satisfy the transportation need.

A National Cooperative Highway Research Program (NCHRP) Synthesis of Highway Practice on Multimodal Evaluation in Passenger Transportation (11) reviews several multimodal evaluation projects undertaken in the United States and Canada prior to 1992. This synthesis concluded that "*. . . new training, assistance, and guidelines for multimodal evaluation should be provided at the national level.*" Also, it was concluded that the lack of commonly accepted multimodal measures of mobility hinders effective multimodal evaluation. The synthesis did identify criteria categories for multimodal comparisons (Table 4).

Table 3. Criteria for Goal-Achievement Evaluation (Adapted from Reference 9)

Goal	Objective	Evaluation Measure
Improve multimodal balance	Ridership levels	Number of weekday person trips Weekday mode-split percentage
	Revenue-cost viability	Annual revenue to operating cost ratio
	Investment efficiency	Annual operating cost/passenger*km Annual capital cost passenger*km
	Implementation feasibility	Future revenue to operating cost ratio Future revenue to total cost ratio
	Geographic balance	Modal improvement costs by county
	Modal coordination	Number of multimodal terminals Judgmental rating if improvement staging
Effectively meet interregional travel demands	Multimodal rights-of-way	Bimodal route distance Trimodal route distance
	Collection-distribution interfaces	Judgmental rating by mode
	Capacity-demand balance	Volume-capacity ratios on peak links (public modes)
Minimize undesired social, economic, and environmental impacts	Coastal environment	Judgmental rating by mode
	Open space resources	Designated open space and parks consumed
	Ecological and historical resources	Number of intrusions on historical or archaeological sites
	Agricultural resources	Agricultural land consumed Vacant land consumed
	Transportation noise	Noise level at 15 m Maximum frequency of service

Table 4. Classification of Criteria (Adapted from Reference 11)

General Category	Typical Criteria	
1. Transportation System Performance	Number of trips by mode Vehicle miles traveled Highway level of service	Peak hour congestion Transit boardings Congestion
2. Mobility	Improved movement of people	Mobility options
3. Accessibility	% within 30 minutes, etc. Transit and highway speeds	
4. System Development, Coordination and Integration	Projects in existing plans Transportation system development	Terminal transitions Regional importance
5. Land Use	Compatibility with land use plans	Growth inducement
6. Freight	Reduced goods movement costs	
7. Socioeconomic	Homes or businesses displaced Maximize economics benefit Construction employment	Historic impacts
8. Environmental	Air quality Natural environment	Sensitive areas
9. Energy	Energy Consumption	
10. Safety	Annual accidents by mode	Safety ratings
11. Equity	Equity of benefit and burden	
12. Costs	Capital costs	Operating costs
13. Cost Effectiveness	Annualized costs per trip or mile	FTA index
14. Financial Arrangements	Funding feasibility - Build/operate Public/private sources	Funds required
15. Institutional Factors	Ease of staging and expansion Non-implementation agency support	
16. Other	Right-of-way opportunities Enforcement	Fatal flaw Recreation

Post-ISTEA Methodologies

Several research studies since the implementation of ISTEA have examined performance measures in the context of multimodal analyses. These studies build upon past research and practice, but acknowledge the multimodal context of ISTEA and the metropolitan planning regulations issued by FHWA/FTA. This section contains a discussion of these studies and related studies.

A study performed by Cambridge Systematics (12) for FHWA examined the performance measure needs for congestion management systems. Cambridge Systematics found a wide range of measures in their review of the practice for corridor analyses (Table 5).

Table 5. Performance Measures for Congestion Management Systems (Adapted from Reference 12)

Measure Category	Performance Measure
Time-Related	average travel speed average travel time average travel rate travel time contours origin-destination travel time percent travel time under delay conditions percent of time average speed below "X"
Volume	VMT/lane mile traffic volume
Congestion Indices	congestion index Roadway Congestion Index TTI's Suggested Congestion Index Excess Delay
Delay	delay per trip delay per VMT minutes miles of delay delay due to construction/incidents
Level-of-Service	lane-miles at/of LOS "X" VHT/VMT at/of LOS "X" predominant intersection LOS number of congested intersections
Vehicle Occupancy/Ridership	average vehicle ridership vehicle occupancy

NCHRP Project 7-13, *Quantifying Congestion*, performed by Lomax et al. (13,14) found that travel time-based measures were the most appropriate for measuring congestion, and that travel time-based measures were applicable for a wide range of single-mode and multimodal analyses. The following measures were listed as applicable for multimodal corridor analyses:

- average travel rate;
- delay rate;
- total delay;
- relative delay rate;
- delay ratio;
- person-speed; and,
- corridor mobility index.

Meyer (15) presents a similar case for travel time-based measures in a performance-based planning process. In his study, Meyer concludes that mobility and accessibility should be important measures of system performance, and that travel time and related measures and availability of alternative modes should be the foundation of mobility measures. Ewing (16) also suggests transportation performance measures such as VMT/VHT, emissions per hour, accessibility (based upon travel time), average vehicle occupancy, average speed for areawide analyses, and average walk-bike share of modal travel.

There is a series of NCHRP projects currently underway that deal with different aspects of multimodal transportation planning (17,18,19). The projects are as follows:

- Project 8-32(1), Innovative Practices for Multimodal Transportation Planning for Freight and Passengers;
- Project 8-32(2), Multimodal Transportation: Development of a Performance-Based Planning Process;
- Project 8-32(3), Integration of Land Use Planning with Multimodal Transportation Planning;
- Project 8-32(4), Developing and Maintaining Partnerships for Multimodal Transportation Planning; and,
- Project 8-32(5), Multimodal Transportation Planning Data.

These projects are expected to contribute significantly to the state-of-the-practice in multimodal transportation planning.

Total Cost Comparisons

Recent research on the comparison of multimodal transportation projects has focused on the use of total cost analysis. By reducing the impacts of transportation improvements to costs and benefits with monetary units, a less biased comparison between multimodal alternatives can be made.

A 1973 NCHRP report by Frye (20) presented an early study to develop a framework to compare transit and highway improvements simultaneously. This study looked at urban system planning and suggested that the evaluation framework for multimodal comparisons be structured around a benefit-to-cost ratio concept. The following improvements were added to the traditional benefit-to-cost analysis practiced at the time of publication:

- transit and highway improvement proposals tested and evaluated simultaneously;
- test process and measurement techniques were applied uniformly to all alternatives;
- common viewpoints regarding opportunity cost of capital and social profit were adopted;
- process is sensitive to the interaction between different transportation modes in the system; and,
- process is open to the addition of new evaluation criteria as research improves their quantification under a benefit/cost analysis.

The framework for comparison is an attempt at removing bias from the analysis of multimodal alternatives by taking into account the full costs and benefits of a project instead of simply accounting quantifiable benefits and costs.

The impacts considered by Frye included quantifiable economic impacts, quantifiable non-economic impacts, non-quantifiable impacts, and policy issues. At the time of the report, techniques for estimating non-quantifiable impacts and policy issues were not sufficiently developed for inclusion in the analysis. The impacts considered are listed in Table 6.

Table 6. Impacts of Transportation Systems Considered by Frye (Adapted from Reference 20)

Monetary Costs	Other Costs
Cost of proposed system plans	Auto terminal time penalties
Maintenance costs	Value of comfort and convenience
Relocation costs	CBD traffic
Parking costs	Number of persons displaced
Transit operating costs	Number of businesses displaced
Variable private vehicle operating costs	Air pollution emissions
Fixed cost of automobile ownership	Through traffic on local street
Accident costs	Noise pollution impacts
Travel-time costs	Latent demand for transportation service

Rahmann and Davidson (21) suggested considering a transportation improvement as a productive enterprise with an output of person trips paid for by the cost of travel measured not in monetary terms, but in minutes per mile. The supply and demand functions for travel are determined and an equilibrium market solution is found. This method has the advantage of allowing evaluation of transportation improvement projects at different stages of implementation. For the comparison of public transportation mode projects along with highway improvements isoquant and isocost lines are developed between two or more alternatives. An optimal solution is found where the highest isoquant line (highest quantity served) is tangent to the lowest isocost line (lowest cost of two or more mode choices). The analysis becomes more complicated with the addition of more than two alternatives.

Freeman and Hutchinson (22) expanded on the research of Rahmann and Davidson. Travel within an urban corridor is assumed to be accomplished by multimodal means. The optimal balance between modes in a corridor is determined by economic evaluation based on the theory of production similar to the method described by Rahmann and Davidson. This approach attempts to account for more complete accounting of the costs of alternatives. Elements of the cost function suggested by Freeman and Hutchinson include:

- land acquisition;
- traveled way and structures;
- rolling stock;
- parking facilities;
- maintenance;
- operation; and
- overhead and administration.

Also included are non-perceived user costs of automobile operation. It is recognized that this list is incomplete and that not all elements in this cost function will be valid for different modes.

DeCorla-Souza and Jensen-Fisher (23) and DeCorla-Souza (24) suggests a total cost analysis of different transportation improvements. By accounting for the total costs, including public costs incurred by non-transportation agencies, fixed private costs, and external social and economic cost, different modal and multimodal comparisons can be made without bias. Examples of the computation of the costs involved is documented in the literature. Total costs for alternatives are divided by the number of person trips served to measure the effectiveness of an alternative. This method allows cross-modal and policy alternative comparisons.

A total cost methodology has been formulated into the Sketch Planning Analysis Spreadsheet Model (SPASM) (25). SPASM accounts for:

- the discounting of costs and benefits over time;
- the congestion-related effects of changes in vehicle miles of travel on speeds during peak and off-peak periods;

- diversion of traffic among parallel highway facilities in a corridor;
- induced traffic occurring as a result of changes in highway congestion levels;
- the effects of speed and cold starts on motor vehicle emissions and fuel consumption; and,
- the benefits to traveler resulting from increased trip-making due to travel time and costs savings.

In an effort to account for the full cost of urban passenger transportation, researchers at the University of Texas (26) developed a model that identifies the full system costs of transportation by automobile, bus, and light rail. By accounting for the cost per person-mile of travel for each of these modes, a method of comparing modes by their full cost is achieved. Table 7 summarizes the cost components by mode used in this methodology. This methodology has been developed into a computer software package called MODECOST.

Table 7. Full Cost Components of MODECOST (Adapted from Reference 26).

	Private Vehicle Users	Transit Bus Users	Transit Rail Users
Facility Cost	Capital Non-Capital	Capital Non-Capital	Vehicle Guideway Station ROW, Yards, Shops
External Cost	Travel Time Air Pollution Incident Delay Accident Other	Travel Time Air Pollution Incident Delay Accident Cost Other	Travel Time Air Pollution Other
Other Costs (Personal or Transit Agency)	Operating	Vehicle Station Operating	Operating

Litman (27) developed a list of twenty transportation cost categories. These cost categories are summarized in Table 8. Litman's research concluded that external, non-market and fixed costs are significant portions of the total cost of transportation. External costs are not perceived by the users and are therefore not considered in the travel decision process leading to inefficient travel decisions. Non-market costs are difficult to quantify and may lead to planning decisions which result in negative net benefits to society. Fixed internal costs tend to suffer from large economies of scale which encourage increased travel, lowering average costs, which leads to inefficiencies.

Table 8. Transportation Cost Categories from Litman (Adapted from Reference 27)

Cost	Internal/External	Fixed/ Variable	Market/ Non-Market
Vehicle Ownership	Internal	Fixed	Market
Vehicle Operating	Internal	Variable	Market
Operating Subsidies	External	Fixed	Market
Travel Time	Internal	Variable	Non-Market
Internal Accident	Internal	Variable	Non-Market
External Accident	External	Variable	Non-Market
Internal Parking	Internal	Fixed	Market
External Parking	External	Fixed	Market
Congestion	External	Variable	Mixed
Road Facilities	External	Variable	Market
Roadway Land Value	External	Variable	Mixed
Municipal Services	External	Variable	Market
Equity & Option Value	External	Variable	Non-Market
Air Pollution	External	Variable	Non-Market
Noise	External	Variable	Non-Market
Resource Consumption	External	Variable	Non-Market
Barrier Effect	External	Variable	Non-Market
Land Use Impacts	External	Variable	Non-Market
Water Pollution	External	Variable	Non-Market
Waste Disposal	External	Variable	Non-Market

MIS Case Study Examples

This section summarizes examples of MISs that have been or are currently being undertaken across the United States. Several of the case studies have been summarized from literature provided at the Transportation Research Board's Conference on Major Investment Studies, sponsored by the FTA and FHWA, in San Francisco, February 1996 (28).

US 301 South Corridor Transportation Study, Maryland

The fifty-mile US 301 corridor stretches from Bowie, Maryland to the Maryland-Virginia border. The highway exists as a major suburban arterial and has become congested in the recent years. In the 1980s, this corridor was studied as a possible location for a new limited access eastern bypass. This option met with considerable public opposition and was dropped from further consideration. In a separate study from the same period, transit improvements were examined.

A MIS has been undertaken by the Maryland Department of Transportation to address the current and future needs of the US 301 corridor. The MIS includes a broad set of highway, transit, and policy options, including:

- a six-lane fully controlled access highway with 23 traffic lights replaced by a minimum number of interchanges;
- a light rail line along US 301 and Maryland Highway 5 connecting to a future Metrorail Station;
- commuter rail on existing tracks that parallel US 301;
- HOV lanes on US 301 and parallel facilities;
- increased local and express bus service;
- park-and-ride lots;
- telecommuting centers; and
- land use policy changes.

These options were combined into strategy packages that emphasized:

- TDM;
- highway/transit upgrade;
- HOV/bus;
- fixed guideway; and
- new highway construction.

These strategies are being explored through an extensive outreach program which includes a 76-member task force.

Miami East-West Multimodal Corridor Study, Florida

Currently there is only one major east-west route in south Dade County: State Road (SR) 836. This corridor connects the airport, seaport, downtown Miami, Miami Beach, and other activity centers. Congestion on SR 836 and parallel streets has increased and long delays occur throughout most of the day. The Florida Department of Transportation has adopted a statewide policy of limiting the expansion of highways to six lanes plus four HOV or express lanes.

A MIS was undertaken to study the corridor. Florida DOT is serving as the lead agency for the MIS and FHWA is serving as lead federal agency for the EIS. Technical and policy committees have been formed to guide the process. The committees consist of:

- FDOT;
- Metro Dade Transit Agency;
- Dade County Metropolitan Planning Organization;
- City of Miami;
- Dade County Airports Authority;
- Tri-County Commuter Rail Authority;
- Port of Miami;
- FHWA; and
- U.S. Coast Guard (USCG).

With FHWA's position as lead federal agency has come the responsibility of organizing other interested federal agencies. With the coordination of FHWA, the following agencies signed a Memorandum of Understanding with Florida DOT to establish each agency's role and responsibility to ensure conformance with NEPA and the federal metropolitan planning regulations. These federal agencies are FTA, U.S. Coast Guard, Federal Aviation Administration, Federal Railroad Administration, and the Maritime Administration. These agencies are also cooperating agencies for the EIS.

Alternative modes being considered in the East-West Corridor MIS are:

- Transportation system Management including highway operation improvements and expanded bus service;
- Widening SR 836 to add general purpose and HOV lanes, express bus service;
- Highway operation improvements plus heavy rail and light rail transit, including exclusive rail service from the airport to the seaport; and
- HOV lanes and rail transit.

Central County Corridor Study, California

The Orange Country (California) Transportation Authority (OCTA) has initiated a MIS to study multimodal solutions for the Central County Corridor. The Central County Corridor, extending between the cities of Irvine and Fullerton is about 28 miles long and six miles wide. Growth in the Corridor has outpaced improvements in transportation infrastructure and services, resulting in severe congestion. Located in a severe non-attainment area, finding ways to decrease congestion and mobile source emissions is a priority.

The primary goal of the MIS is to find ways to solve the mobility and congestion issues in a manner that is consistent with regional air quality guidelines. Participating in this effort are the OCTA, Orange County, seven cities, and members of the public and business communities. Cooperation between these groups is vital for the success of this MIS. Direct mailing and open house forums were methods used to contact the public and initiate dialog concerning the MIS. Advisory committees consisting of city, local agency, and community leaders have been formed to guide the MIS process.

Six alternative strategies have been identified as possible courses of action including:

- Construction of those projects already funded;
- TSM strategy;
- Improved bus service in the corridor;
- Construction of additional HOV and transit lanes; and,
- Two fixed guideway options.

Key consideration in choosing alternatives include:

- improvement of connectivity between activity centers;
- effectiveness in addressing suburb-to-suburb peak and non-peak trips; and
- extent to which alternatives can be integrated to support existing improvements.

Pocatello/Chubbuck Corridor Transportation Study

The Pocatello/Chubbuck metropolitan area is a relatively small planning district at 55,000 residents, but has experienced significant residential growth. The growth has lead to congestion in the IH-15 and IH-86 corridors. In response to the ISTEA planning regulations and requirements for MIS, the Bannock Planning Organization requested that the Idaho Department of Transportation initiate a MIS to clearly define the congestion in the corridor and develop a clear congestion relief strategy.

Transportation planners undertaking this MIS actively solicited early public involvement in the study. After state and local agencies developed a set of preliminary project options, the public was invited to provide input into the study. The result was the identification of twelve possible alternative concepts including roadway improvements, TDM concepts, and improvements to the local bus system.

To refine these alternatives, the Bannock Planning Organization and Idaho DOT initiated newspaper surveys and "listening posts." The surveys asked residents to describe their perceptions of the transportation problems in the corridor and rank alternative improvements. The "listening posts" were information booths set up in public areas which allowed planning staff to be available to answer questions. These efforts narrowed the number of alternatives to four, which were presented to the public at an open house. Utilizing public input and the criteria set forth by ISTEA, a locally preferred alternative was chosen that came directly from the public involvement process. The proactive public involvement in this process lead to a streamlined Environmental Assessment under the NEPA process, shortening the traditional environmental review process by six months.

State Highway 152 Corridor Study, Oklahoma

The Oklahoma State Highway (SH) 152 corridor is located in the southwest portion of Oklahoma City, and comprises a study area distance of approximately four miles. SH 152 is currently a two lane, unlimited access facility in a high-growth area of Oklahoma City. Because of concern for safety and highway capacity, the need for an upgrade to this corridor has been recognized for several years. A 1986 Finding of No Significant Impact as a result of the NEPA process approved a capacity expansion for a section of SH 152 and a realignment for others. However, no corridor improvements were implemented.

With increased growth in the early 1990s, the City of Oklahoma City began to question the improvements to SH 152 that were recommended from the NEPA process in 1986. A MIS was initiated to examine the potential of new alignments, consider different modes or combinations of modes, and involved the public in the decision-making process. The City of Oklahoma City assumed the responsibility as lead agency for the MIS and sought early involvement of federal, state, and regional transportation agencies in the study.

The MIS re-examined the improvements suggested from the 1986 study and included new alignments, transit, bicycle, pedestrian and park-and-ride considerations, as well as the relationship of the corridor to trucking, rail, and air travel. By examining density and land use patterns in the area, the MIS concluded that the corridor was predominantly tied to auto travel. The MIS focused on evaluation of the most appropriate means to serve corridor needs, and considered the associated social, economic, and environmental impacts of alternatives.

I-435 Major Investment Study, Kansas City, Missouri

Increasing traffic congestion along I-435 from the Grandview area to the Claycomo area of Kansas City, Missouri has prompted the I-435 MIS. The study, conducted by the Missouri Highway and Transportation Department (MHTD), is designed to weigh all factors that affect potential solutions to identified traffic problems along this segment of I-435. Foremost among those factors are the suggestions and concerns of the public.

The MIS is being overseen by representatives from FHWA, FTA, Mid-America Regional Council, Kansas City Area Transportation Authority, state and federal resource agencies, and affected local governments. Business leaders, government officials, and civic organizations have been encouraged to participate in the study.

The MIS seeks to address the following concerns:

- system preservation;
- personal mobility;
- quality of life (noise, air quality, and visual);
- land use, development, and regional economy; and,
- system management and efficiency.

The following strategies have been identified for further analysis in the IH-435 MIS:

- No-build;
- Roadway improvements with ITS;
- Roadway improvements with ITS and bus service improvements;
- Roadway improvements with ITS, bus service improvements and HOV lanes; and,
- ITS, bus service improvements and HOV lanes.

With a proactive public involvement process that includes a World Wide Web page (29) with information on the project, the MIS process is moving forward to identify the transportation needs of the corridor.

Summary of Literature Review

The Intermodal Surface Transportation Efficiency Act of 1991 and the supporting FHWA/FTA regulations changed the manner in which metropolitan transportation planning is performed. One of the requirements of the new legislation, the MIS, is meant to increase the level of information available to transportation planners when making decisions on major transportation improvements in a corridor or subarea.

A MIS is to be performed in a cooperative manner between all transportation stakeholders and affected citizens and businesses in a metropolitan area. Organization of the process is important to assure that the study is efficient. An early statement of transportation problems or goals that will be answered by the MIS is important to focus the MIS process.

The development and evaluation of alternatives is the purpose of a MIS, and thus the most important element. In the spirit of multimodalism expressed in ISTEA, alternatives in a MIS must be comprehensive and multimodal. All reasonable alternatives should be considered in the analysis. Evaluation should not be biased to any alternative whether based on mode, cost, or any other specific variable. However, the evaluation should clearly identify the differences between alternatives to allow decision-makers to come to the best possible locally preferred alternative for inclusion in the MTP or TIP.

One important issue regarding the performance of a MIS is integration with the NEPA process. The FHWA/FTA regulations provide the transportation planner with two options. Option I is sequential. The MIS is performed and the locally preferred alternative is used as an input into the NEPA process. Option II is concurrent. The MIS is created at the same time as a draft Environmental Impact Statement or Environmental Assessment. Both of these options have concerns. Reaching a locally preferred alternative outside the NEPA process, as in Option I, may not be acceptable to environmental agencies responsible for overseeing the NEPA process. The level of engineering detail required for a MIS is less than the detail for an EIS or EA, leading to a more expensive MIS under Option II.

With the requirement of a MIS comes the need for multimodal measures to compare multimodal alternatives. The pre-ISTEA planning process largely separated transit planning from highway planning. Different measures were used to compare transit projects and highway projects. Many different approaches to decision-making have been suggested. Such methods as impact assessment, economic efficiency, goal achievement, and total cost analysis have been suggested as a means to facilitate decision-making. An increasing emphasis has been placed on quantifying impacts in monetary terms. This allows for what is known as a total cost-benefit analysis.

Past research indicates that many commonly used measures can be applied to multimodal situations. Such measures as person miles of travel, travel time, and benefit-to-cost ratio are applicable across modes and can be used directly in many of the decision making approaches discussed in the proceeding paragraph. With an increase in emphasis on environmental and social impacts of transportation, such measures as energy consumption, air pollution emissions, and number of displaced homes and businesses have been cited as appropriate measures. In total cost-benefit analysis, these same measures can be converted into monetary terms.

This chapter concluded with examples of MISs being undertaken across the United States. These examples show the broad nature of institutional arrangements, public participation activities, and alternatives considered.

CHAPTER III. FINDINGS

This chapter presents the findings of the study, and draws heavily upon the state-of-the-practice review of major investment studies (MISs) in Texas. All MPOs in Texas were contacted about planned and ongoing MISs, and documentation on the MIS process and findings were gathered where possible. Case studies in this chapter summarize selected MISs that are being conducted in Texas, and highlight basic study scope and unique characteristics of each MIS. This chapter also presents and describes measures of effectiveness (MOEs) that were found in the literature review and in the Texas MIS case studies. Evaluation criteria are presented to assess the MOEs, and a qualitative assessment of the MOEs is provided.

State-of-the-Practice Review of Major Investment Studies in Texas

This section provides a summary of selected MISs that are being conducted in the state of Texas. Table 9 lists the urban areas in Texas and the MISs that are in progress or being considered. The summaries for each MIS outline the study background, alternatives considered, analysis techniques, and unique characteristics. The review is arranged alphabetically by urban area (as shown in Table 9).

Table 9. Summary of Texas Urban Areas and Major Investment Studies

Urban Area	Metropolitan Planning Organization (MPO)	Major Investment Study Corridor/Area	Status of MIS (as of Aug. 96)
Abilene	City of Abilene	Loop 322	Completed
Austin	Austin Transportation Study	IH-35	In Progress
		SH 130	In Progress
		US 183A	Scoping
Brownsville	City of Brownsville	US 77/83	Scoping
Copperas Cove	Central Texas Council of Governments	US 190 (Copperas Cove Bypass)	In Progress
Dallas-Ft. Worth	North Central Texas Council of Governments	IH-635 (LBJ Freeway)	In Progress
		Loop 9 (South Outer Loop)	In Progress
		Northeast Corridor	In Progress
		Trinity Parkway	In Progress
El Paso	City of El Paso	Border Highway Extension	In Progress
Harlingen-San Benito	Harlingen-San Benito Metropolitan Planning Organization	US 77/83	Scoping
Hidalgo County/McAllen	Lower Rio Grande Valley Development Council	US 83	Scoping
Houston	Houston-Galveston Area Council	IH-10 (Katy Freeway)	In Progress
Laredo	Laredo Urban Transportation Study	US 83	Scoping
San Antonio	Bexar County Metropolitan Planning Organization	IH-35 (Northeast Corridor)	Completed
		IH-410	Completed
Texarkana	Arkansas State Highway Department	IH-49 Extension (EIS)	Completed
Tyler	City of Tyler	Loop 49	Completed
Waco	City of Waco	Waco Drive	Completed

Abilene--Loop 322

Loop 322 is an improvement in the Abilene area which has been planned for sometime. Final planning decisions regarding this project had been made prior to the establishment of the FHWA/FTA planning regulations which require a MIS to be performed for a project such as Loop 322. A stakeholders meeting was convened to determine the feasibility of performing a MIS of the corridor. It was determined that a report published as a result of this meeting was sufficient and a full MIS was not necessary for this project.

Unique Qualities. This study was done using the Delphi method, which involves the cooperation of all involved parties to come to a decision given the opinions of all present. In attendance were TxDOT planning coordinators, area engineer, design coordinator, environmental coordinator, transit system representative, county commissioner, city planner, MPO transportation director, and the airport manager.

Evaluation of Alternatives. The following alternatives were considered:
1. Do Nothing;
2. Proposed widening of Loop 322 from 2 lanes to 4 lanes;
3. Enhancement to existing transit service; and,
4. Develop an alternate route.

Measures of Effectiveness. Each of the following factors were given a score, decided on by those present, between 2 for a positive impact and -2 for a negative impact:
- land use;
- access;
- safety;
- intermodal connection;
- population (impacts on adjacent population);
- environmental (air, noise, wetlands, and wildlife habitat);
- tourism;
- operation and maintenance;
- person mobility;
- freight mobility;
- system continuity;
- economic development; and,
- storm water management.

Findings. This project is not technically a MIS. Although it was approved as one, it does not include all of the important elements of a MIS. Public involvement was not included and the cost-effectiveness of alternatives was not explored. Only a qualitative assessment of impacts was undertaken.

The City of Abilene was forced to respond to a changing regulatory environment regarding transportation planning and was successful in their efforts. Although this MIS is not the best example of how to undertake the process, it did include a recognition of important impacts applied to multimodal alternatives which is within the spirit of a MIS and ISTEA.

Austin--IH-35

Several studies have been conducted since 1987 to determine a solution to the increasing traffic congestion problems on IH-35 through the Austin Metropolitan area. The section through downtown Austin is considered a "choke point" between Mexico and Canada on this important international route. The citizens of Austin incur daily losses from increased environmental pollution, decreased travel times, and a high accident rate. With the passage of the ISTEA in 1991, it was determined that a MIS would be required to determine the locally preferred alternative for this important transportation corridor. Begun in July of 1992, the MIS is lead by the Texas Department of Transportation (TxDOT) with participation of the following agencies on the IH-35 Interagency Development Team: FHWA, Austin Transportation Study (ATS), City of Austin, Capital Metro Transit Authority, Travis County Public Improvement and Transportation Department, and the Texas Transportation Institute.

Evaluation of Alternatives. The IH 35 MIS has identified six strategy alternatives:

- No build;
- No build with light rail improvement;
- Transportation system management (TSM) with light rail and transportation demand management (TDM);
- Convert travel lane to HOV with light rail and TDM;
- Construct HOV with light rail and TDM; and,
- Rebuild IH-35 with light rail and TDM.

The rebuild IH 35 alternative has been further refined into five design alternatives:

- Rebuild IH 35;
- Rebuild with HOV lanes;
- Rebuild with HOV lanes and a southbound collector-distributor road;
- Rebuild with elevated collector-distributor lanes in both directions; and,
- Rebuild with HOV lanes and elevated collector-distributor lanes in both directions.

Also, the multimodal nature of ISTEA is recognized in the study, and the following modes and modal interfaces will be analyzed: automobiles, carpools, van pools, buses, trucks, light rail, bicycles on the frontage roads, and pedestrians.

Measures of Effectiveness. The IH-35 MIS will examine the following effects of transportation improvement alternatives:

- Mobility improvements-generalized statements;
- Social, economic, and environmental effects;
- Safety;
- Energy consumption and operating efficiencies;
- Land use and economic development-generalized;
- Financing; and,
- Cost effectiveness.

The specific measures of effectiveness used for peak period analysis have been tentatively decided to be:

- Hydrocarbon emissions (system wide);
- Carbon monoxide emissions (system wide);
- Nitrous oxide emissions (system wide);
- Fuel consumption;
- Peak period speeds acceptable to public;
- Travel time (pasenger-hours and vehicle-hours);
- Delay time (pasenger-hours);
- Travel distance (pasenger-miles); and,
- Other measures to be determined at a later date.

Once the first phase of analysis has been complete and specific alternatives have been identified for further analysis, the following costs will be included in further analysis:

- Transit-only, related construction costs;
- Highway related construction costs;
- Other modal construction costs; and,
- Maintenance and operations costs.

Findings. This study is in the preliminary stages of development. It is unique in its multimodal scope and the cooperative nature of arrangements made between effected agencies. Also, TxDOT is trying to increase public involvement with the project by publishing MIS-related information on their World Wide Web site.

Austin--SH 130

State Highway 130 is a new transportation project that has been planned for the Austin area. This highway would serve to relieve congestion on IH-35 through central Austin and provide a bypass route for truck traffic. This facility would also support travel demand and land use management goals of Austin by providing and accommodating roadway operational improvement measures, public transportation and bicycle/pedestrian/trail improvements where practical.

Unique Qualities. This study involves planning for an entirely new section of facility including route alignment. There is a great deal of demand for this facility based on growth projections for the Austin Metropolitan Area, however, there has been much debate over its alignment.

Evaluation of Alternatives. The SH 130 MIS included reviewing the construction of three segments of roadway. These segments were divided into:

Section A - IH-35 near Georgetown to US 290 east of Austin
Section B - US 290 east of Austin to FM 1327
Section C - FM 1327 to US 183

Seven alternatives were considered for possible combinations of the segments listed above. Each of these routes had transit(not including rail), high-occupancy vehicle facilities, freight by rail, and bicycle/pedestrian facilities considered as possibilities for the route when it was evaluated.

1. Build All (A,B,C);
2. No Build (do not build A,B,C);
3. Build A and B only;
4. Build A and B to SH 71;
5. Build A;
6. Build B; and,
7. Build All with alignment east of Decker Lane.

Measures of Effectiveness. The SH 130 MIS uses the following set of criteria and measures to evaluate alternatives in the analysis.

- cost effectiveness;
- person-hours of delay;
- ton-hours of delay;
- level of service (v/c ratio);
- average daily traffic;
- vehicle-miles of travel;
- person-miles of travel;
- ton-miles of travel;
- human environment (growth, noise, aesthetic value, economy, etc.);
- natural environment (water, air, vegetation, wildlife, geology, etc.); and,
- historical and archaeological.

Findings. There have not been any recommendations made to this point. The Draft MIS report has not been released. The information above has been made available in scoping and public meetings.

Dallas-Ft. Worth--IH-635

A MIS is being conducted on IH-635 (LBJ Freeway) in north Dallas to find solutions to improve mobility. The study corridor is approximately 21 miles in length, stretching from the eastern suburbs to the northwest corner of Dallas. The IH-635 corridor had been the focus of a corridor study in 1987, which recommended a technically preferred alternative. The technically preferred alternative met with substantial opposition from the residential and business community, who were concerned about the reconstruction impacts and a reduced regional construction budget. A study of the IH-635 corridor was re-initiated in 1993, and shortly after commencement, it was decide that the corridor study should comply fully with federal regulations for a MIS. The objectives of the IH-635 MIS are the following:

- *"Accept future freeway congestion in the peak hour, and offer carpool and/or transit options as a means to avoid congestion;*
- *Minimize vehicle-miles of travel and maximize passenger-miles of travel in the corridor;*
- *Provide for desirable levels of access within acceptable design criteria and operate to maximize freeway traffic flow conditions; and,*
- *The most cost-effective alternative is equivalent to the least public cost alternative, where construction, operation, and congestion costs are considered."*

Evaluation of Alternatives. There are 13 concepts defined in the IH-635 MIS, and each concept include baseline projects and regional transportation demand management strategies. The individual concepts include different variations and combinations of general-purpose freeway lanes, high-occupancy vehicle lanes, express lanes, and frontage roads. The conceptual alternatives, by number, include the following:

1. No-build: baseline projects and regional TDM activities;
2. Corridor TDM activities, TSM projects;
3. 8 general-purpose lanes, 2-lane HOV/express, 4/6-lane frontage roads;
4. 8 general-purpose lanes, 2-lane reversible HOV/express, 4/6-lane frontage roads;
5. 10 general-purpose lanes, 2-lane HOV/express, 4/6-lane frontage roads;
6. 10 general-purpose lanes, 2-lane reversible HOV/express, 4/6-lane frontage roads;
7. 8 general-purpose lanes, 4-lane HOV/express, 4/6-lane frontage roads;
8. 10 general-purpose lanes, 4-lane HOV/express, 4/6-lane frontage roads;
9. 6 general-purpose lanes, 4 variable use lanes, 4 express lanes, 8-lane bi-directional frontage roads;
10. 8 general-purpose lanes, 4-lane HOV, 4 express lanes, 8-lane bi-directional frontage roads;
11. 8 general-purpose lanes, 4-lane HOV, 4 express lanes, 4/6-lane frontage roads;
12. 6 general-purpose lanes, 4-lane HOV/express, 4 express lanes, 4/6-lane frontage roads; and,

13. Cut-and-cover facility, 8 general-purpose lanes, 6-lane HOV/express, 4/6-lane frontage roads.

The IH-635 MIS uses three different sets of criteria and measures to evaluate alternatives in different stages of the analysis. The first criteria set is designed to narrow the selection of alternatives, and includes measures and criteria that is easily calculable using models or subjective judgement. The measures and criteria used in first stage of analysis are:

Quantitative Measures

Travel Demand
- person-miles of travel;
- LBJ traffic projections (forecast volumes at 17 locations);

Travel Performance
- person-hours of travel;
- person-hours of congestion delay;
- percent of increased travel time due to congestion;
- average congested speed;
- congestion delay per mile;

Corridor Air Quality Impacts
- tons of volatile organic compounds (HC and CO);
- tons of oxides of nitrogen (NO_x);

Corridor Congestion Costs
- dollars;

Qualitative Measures

General Right-of-Way Impacts (minimal, moderate, extensive);

General Visual Impacts
- visual aesthetics (similar to existing, increased, decreased);
- commercial exposure (similar to existing, increased, decreased);

General Accessibility
- IH-635 facility access (similar to existing, increased, restricted);
- adjacent property access (similar to existing, increased, restricted);

General Noise Impacts
- noise source: freeway (similar to existing, increased, decreased);
- noise source: frontage road (similar to existing, increased, decreased);

Operational Flexibility (potential ability to change lane configuration/usage to short-term operation demands, yes/no); and,

Multimodal Flexibility (ability to accommodate multiple modes, including HOV, buses, transit, bicycles, pedestrians, and single occupancy vehicle, yes/no).

The measures and criteria used in the second stage of the IH-635 MIS analysis include those in the first stage and the following:

- specific right-of-way impacts;
- specific visual impacts;
- accessibility;
- constructability;
- specific noise impacts;
- design flexibility;
- number and valuation of developments displaced;
- safety impacts;
- revenue generation potential;
- capital costs;
- operating and maintenance costs;
- cost-effectiveness;
- general biological and physical resources; and,
- general social and neighborhood issues.

The third stage of the IH-635 analysis is the environmental assessment. The criteria and MOEs considered in the third stage include those in the first and second stage, and those environmental criteria necessary to satisfy the NEPA/EIS requirements.

Findings. The IH-635 MIS linked the evaluation criteria and MOEs to regional goals that were established early in the MIS process. The MIS analysis process used different sets of evaluation criteria to screen alternatives and prevent excessive use of resources early in the study. The IH-635 MIS is involving the public throughout the entire process, and as a result, should have more community buy-in for the locally preferred alternative. This MIS did not include any fixed-rail transit, but did heavily emphasis the HOV/transit preferential lane concept.

Dallas-Ft. Worth--Trinity Parkway

The Trinity Parkway MIS is intended to solve transportation problems along the Trinity River Corridor in Dallas. The Study area includes several major freeway corridors (IH-30, IH-35E, IH-45), their interchanges, and a major open space resource (Trinity River floodway) in the city of Dallas. The mission and goals of the MIS are as follows:

Mission: *The study's mission is to develop a locally preferred action plan to solve transportation problems along the Trinity River Corridor in Dallas, and to integrate with community plans and goals for the Trinity River resource.*

Goals: *The study's goals are:*

- *The action plan must be environmentally, socially, technically and financially feasible.*
- *The action plan must be integrated with community projects and long-range plans in the area.*

- *The study must maintain a local consensus process.*
- *The study must consider all reasonable means and methods to serve the movement of people and goods.*
- *The study must consider national, state, regional and local goals.*
- *The study must ensure proactive, inclusive and continuous public involvement and understanding.*
- *The study should be completed by July 31, 1997.*

Evaluation of Alternatives. Alternative transportation improvements were not clearly defined at the time of this report's publication, but evaluation criteria were developed. The Trinity Parkway MIS will use a relatively small set of criteria and MOEs for the first stage of the analysis (screening of alternatives). Once the number of alternatives has been reduced to a manageable size, a more extensive set of criteria and MOEs will be applied in a second stage of analysis. A third stage of analysis will develop detailed alignments, traffic models, hydraulic models, and financing plans. The conclusion of the third stage of analysis will result in the selection of a locally preferred alternative.

Measures of Effectiveness and Evaluation Criteria. The Trinity Parkway MIS will utilize different sets of criteria and MOEs for different stages of the analysis. The first stage of analysis uses easily calculable measures and impacts, the second stage uses a more comprehensive set of measures and criteria, and the third stage of analysis combines economic analysis with the second stage measures to select a locally preferred alternative.

The criteria and measures to be used in the first stage of analysis include:

- public acceptance (rated as high, medium or low based upon community input);
- environmental effects (compatibility with regional air quality goals);
- mobility benefits (effects on system capacity, both highway and rail transit);
- cost effectiveness and affordability (total project cost, e.g., low, medium, or high);

The criteria and measures to be used in the second stage of analysis include:

- public acceptance (rated as high, medium or low based upon community input);

<u>Environmental</u>

- compliance with regional air quality standards;
- noise effects (calculate noise contours and identify impacted properties);
- effects on ecosystems (narrative description);
- effects on wetlands (acres of affected wetlands);
- effects on flood plains (goal of zero net loss of floodway conveyance);
- effects on archaeological and historical resources (narrative description);
- effects on park lands (acres of direct impact and narrative description);
- hazardous materials (description of affected sites);

Mobility

- effects on travel demand (person-miles of travel for segments in corridor);
- effects on transit or roadway service (vehicle queue lengths, travel times, daily hours of congested conditions, congested speed and congestion delay per mile);
- corridor congestion costs (person-hours of congestion delay and monetary value);
- accessibility (evaluate freeway operation versus estimated benefits to adjacent property);
- effects on safety (determine where design standards can not be met);
- allowance for freight movement (narrative description);
- allowance for pedestrian and bicycle use (narrative description);

Social and Economic Effects

- displacement of residential property (number and value of houses);
- displacement of commercial property (number, area, and value of buildings);
- specific visual impacts (number of linear facility feet above adjacent levee top);
- cumulative effects on neighborhood quality/safety (traffic, noise, services, safety, cohesion);
- land use impacts (narrative description);

Cost-Effectiveness and Affordability

- total construction, right-of-way acquisition, and operations and maintenance cost;
- benefit-cost ratio (annualized cost versus person-trips of added capacity);
- revenue generation potential (potential revenue for variety of pricing schemes);
- affordability (cost allocation among agencies and assessment of funding);
- project flexibility (segments and costs for staged construction);

Compatibility with Other Projects

- Narrative description of compatibility with Dallas Floodway Extension Project, Dallas Floodway Levee Improvements Project, Trinity Floodway Parks and Lakes, and the Dal-Homa Hike/Bike Trail System.

Effects During Construction

- transportation impacts (preliminary evaluation of construction phasing);

The criteria and measures used in the third stage of analysis includes all those measures in the second stage, and any additions or deletions of measures deemed necessary from experience gained in the first and second stages of analysis. The third stage also includes the development of an economic model for identifying the short and long-term effects on economic activity. A financial plan for the locally preferred alternative will also be developed in the third stage.

Findings. The Trinity River MIS defined the MOEs and evaluation criteria early in the analysis and matched the criteria and MOEs to the MIS goals. The evaluation process uses easily calculable measures in early stages of the analysis to screen alternatives, and a more comprehensive set of criteria and measures in later stages of the analysis. The Trinity Parkway MIS evaluation process recognizes the effort required to evaluate many alternatives, and matches the evaluation criteria with the information and estimates available at different stages of the MIS.

Houston--IH-10

In March of 1995, the Houston District of the Texas Department of Transportation began a transportation study of a 40-mile section of the IH-10 (Katy Freeway) corridor from the Houston Central Business District west to the Brazos River. This transportation study was initiated so that the future (Year 2020) transportation needs for the corridor could be evaluated. From this study, TxDOT will now be able to use these evaluations to look at the long term transportation issues and to form the most cost efficient transportation option.

Unique Qualities. In this MIS, both the public and the participating agencies worked together. The involvement between these two entities is a very important part of the study process. A Steering Committee and a Conceptual Alternatives Advisory Committee were both formed in order to develop and assess the transportation alternatives.

Evaluation of Alternatives. The following alternatives are considered:

- No Build;
- Transportation system management (TSM) and transportation demand management (TDM);
- Moderate transit (HOV) and moderate SOV improvements;
- Moderate transit (HOV) and high SOV improvements;
- High transit (HOV) and moderate SOV improvements;
- High transit (Rail) and moderate SOV improvements; and,
- High transit (HOV) and high SOV improvements.

Measures of Effectiveness. Screening criteria were used to compare the categories on the basis of which alternative would best solve the problems of the corridor. The initial screening criteria along with each analysis method are listed below:

Initial Screening Criteria	Analysis Method
• Satisfaction of future person movement demand	Capacity estimates and demand
• Estimated construction cost	Conceptual estimate based on TxDOT unit costs and costs of similar projects
• Need for additional right-of-way/ elevated structure	Visual inspection
• Conformity with air quality plan	Comparison with existing plan
• Improved access to transportation facilities	Qualitative assessment
• Number of travel choices/modes served	Policy assessment
• Service to activity centers	Plan assessment
• Ability to increase capacity/service	Engineering judgement

The next stage in the analysis seeks to identify the preferred alternative. This stage includes greater detail in physical design and travel demand forecasts to best quantify capital and operating costs and determine the person moving impact of alternatives. The following impact categories have been identified along with potential concerns to be addressed in this analysis:

- Land use (historic properties, farmland, and neighborhoods);
- Traffic (freight, public transportation, and travel times);
- Social environment (public health and safety, economic development, and displacement);
- Natural environment (soils, ground water, and biological resources); and,
- Other areas (air quality, noise, aesthetics).

Findings. The aspect of this MIS which seems to be most strongly emphasized is public participation. Over three hundred individuals participated in public meetings and workshops early in the MIS process which has helped define the course of the MIS, both with alternative development and evaluation criteria. At the public meetings, small discussion groups were formed in order to get public input on evaluation criteria. From these sessions and comment forms, the following list of criteria was created and ranked from most important to least important:

- Reducing congestion and improving speed;
- Ability to increase service or capacity in the future;
- Improved access to major destinations;
- More entrances and exits from facility;
- Limitation of ROW additional use;
- Potential impact on air quality; and,
- Cost.

This emphasis on opening the process to active public involvement has lead to a study which is more responsive to the needs of the users of the system. By allowing public input into the determination of evaluation criteria and ultimately, MOEs, the concerns of the public can be integrated into the evaluation process.

Although specific MOEs for use in this study have not been identified at the present time, the criteria which the MOEs will quantify have been identified. The MOEs chosen will quantify the traffic, social, environmental, and land use impacts of the multimodal alternatives.

San Antonio--IH-35

The IH-35 corridor is located in northeast San Antonio, and is a major radial commuting corridor into downtown San Antonio and various activity centers in north San Antonio. The length of the IH-35 corridor under study is approximately 14 miles, and carries about 142,000 vehicles per day for both directions, with year 2015 forecasted volumes approaching 210,000 vehicles per day. The IH-35 corridor runs parallel to a freight rail corridor, and IH-35 itself has high volumes of intercity truck traffic. The IH-35 MIS is being conducted in cooperation with the Texas DOT, the Bexar County MPO, and the VIA Metropolitan Transit Authority.

Evaluation of Alternatives. The following alternatives were considered in the IH-35 MIS:

- No-Build
- Transportation demand management/intelligent transportation systems
- Specific interchange reconstructions
- Addition of express lanes
- Addition of general-purpose lanes
- Addition of truck lanes
- Bus service
- Rail service
- Pedestrian/bicycle improvements.

A screening process was used to narrow the list of conceptual alternatives to between 8 to 12. The screening process used the following broad categories of measures: mobility (travel time for a given trip table), environmental impact (vehicle-miles of travel), affordability (capital cost), growth management (land use density gradients), and economic development (cost of travel and ability to attract external funding). After screening, the following measures were used to evaluate the alternatives:

- hourly person trip capacity for the corridor;
- peak hour v/c ratios and level of service;
- congestion relief index;
- number of economically disadvantaged communities served;
- accommodation of incident and traffic management;
- safety;
- energy consumption;
- operating efficiency;
- incremental cost per new person trip of capacity;
- incremental cost per new non-SOV regional passenger trip; and,
- benefit-to-cost ratio using full costing for benefits.

Findings. Like the MISs in Dallas, the IH-35 MIS used a several tier process to screen and evaluate alternatives. Although IH-35 has been identified as a freight corridor, few measures based on freight capacity or movement were used to evaluate alternatives.

San Antonio--IH-410

A MIS is being conducted on IH-410, extending from IH-35 on the northeast side of San Antonio to IH-10 on the northwest side of the city. The corridor is part of a loop around San Antonio, and serves many commuters that live in the northen suburbs. The corridor also crosses several major north-south routes.

Evaluation of Alternatives. The following alternatives were evaluated for the IH-410 MIS:

- No-Build alternative;
- Transportation demand management/intelligent transportation systems;
- Addition of general-purpose lanes;
- Addition of HOV lanes;
- Addition of general-purpose and HOV lanes; and,
- Addition of elevated express lanes.

Measures similar to the ones used in the IH-35 MIS were used in the IH-410 MIS. These measures and evaluation criteria include:

- capital and right-of-way costs;
- effects on mobility;
- air quality;
- hydrology/water quality;
- soils and unique geological features;
- hazardous wastes;
- noise, vibration, light, and turbulence;
- wildlife habitat and vegetation;
- archaeological and historic sites;
- land use, governmental plans and policies;
- land-use compatibility, neighborhood impacts and displacements;
- economic development;
- safety;
- energy consumption;
- operating efficiency;
- incremental cost per new person trip of capacity;
- incremental cost per new non-SOV regional passenger trip; and,
- benefit-to-cost ratio using full costing for benefits.

Findings. The IH-35 MIS was similar to the IH-410 MIS. Both MISs in San Antonio were Option II's that included the environmental assessments. Many studies had been conducted previously on IH-410, but the MIS permitted extensive public involvement in development and screening of alternatives.

Texarkana--U.S. Highway 71

The improvements in this corridor between Kansas City, Missouri and Shreveport, Louisiana pass through the Texarkana Urban Transportation Area. This necessitated the inception of a MIS.

Unique Qualities. As part of the National Highway System, it was considered appropriate for improvements in the US 71 corridor to be entirely highway improvements. This makes the MIS very simple in that only a resolution from a public meeting stating that transit and other alternative transportation modes were rejected is needed.

Evaluation of Alternatives. Five highway alternatives, a no-build alternative, and a general transit/alternative transportation alternative were scoped. Only three highway alternatives were evaluated in the EIS.

The highway options were evaluated in depth using the following factors:

Roadway/Engineering Issues:(score out of 40)
- total length;
- flood plain road length;
- bridge length at river crossing;
- total cost;
- topography at river crossing;
- earthwork;
- right-of-way acquisition/cost;
- constructability;
- phased construction usability;
- traffic volume (use);
- road user benefit;

Access Issues: (score out of 10)
- access to various local properties;

Environmental Impacts: (score out of 20)
- sulphur river management area;
- oil and gas fields;
- wetlands;
- flood plain;
- fish and wildlife habitat;
- recreational facilities;
- prime farmlands;
- cultural resources;
- unique/natural areas;
- protected species;
- noise;
- air quality;
- hazardous material;

Social Impacts: (score out of 20)
- existing communities;
- farms/homes/businesses;
- construction traffic;
- recreational activities;
- local public;

- local business;
- aesthetics;

Economic Impacts: (score out of 10)

- economic development opportunities;
- economic impact of US 71 corridor;
- agricultural activities;
- oil and gas field activities; and,
- timber activities.

Each item was scored for each alternative from “1" for most negative to “4" for most positive. The scores in each category were than normalized to the weight of the category and summed.

Findings. A majority of this study corridor passes through rural areas, but because it also passes through portions of the Texarkana metropolitan area, it must be considered as a MIS. As a future intercity Interstate Highway corridor, alternatives which do not include a freeway element would be irrelevant. Therefore this study does not contain multimodal alternatives. Also, because the transportation goals of this corridor do not include congestion relief or urban mobility, MOEs such as delay reduction and person movement improvement would not be responsive to corridor goals.

This MIS, which is also a draft EIS, does include assessment of a number of detailed cost, environmental, social, and economic impacts. The detail is consistent with an Option II MIS. The detail environmental impact assessment is indicative of the level of detail need to simultaneously perform a MIS and satisfy NEPA requirements.

Caution should be used when applying many of these MOEs to other MIS. The detailed level of the analysis has lead to many site-specific MOEs. Also, the single mode bias of this study has lead to many MOEs which may only be applicable to the highway mode.

Tyler--Loop 49

Congestion on the current loop (Loop 323) and continued growth of the City of Tyler and Smith County will lead to the need of a second loop around Tyler, Texas. The proposed loop would also serve a NHS bypass of US 69 which currently routes traffic through the center of Tyler or on Loop 323.

Unique Qualities. The MIS contains no quantitative analysis of the problem. Three different alternatives are discussed with do-nothing and upgrades to existing infrastructure being discarded. Transit was initially discussed but rejected with the approval of FTA.

Evaluation of Alternatives. The three alternatives were examined:

- New Loop 49
- Upgrades to existing Loop 323

- Do nothing

There was a qualitative discussion of land use/economic development and environmental considerations. No quantitative MOEs were chosen to compare alternatives.

Findings. The Tyler experience is an example of how simple and straight-forward the MIS process can be if the goals and objectives of transportation improvements are also simple and straight-forward. This MIS contained the minimum number of alternatives and a purely qualitative analysis, however it was within the guidelines of planning regulations by virtue of its acceptance by the FHWA and FTA.

It is obvious that a MIS would not have been performed in this situation without the federal requirement and oversight by the FHWA and FTA. Although different in scope to MISs which are performed in larger urban areas, it was sufficient to meet federal requirements while not being overly taxing on local transportation authorities who do not have the resources of larger urban areas to expend on extensive studies.

Waco--Waco Drive

Increased travel demand on Waco Drive has caused congestion. Due to the restricted nature of the corridor, capacity improvements on Waco Drive would be extremely expensive, therefore a MIS was undertaken to determine alternatives which will be solve the problems in the corridor. A proactive public involvement process with creation of a Citizen's Advisory Committee to help guide the direction of the project and continuous public involvement.

Evaluation of Alternatives. Alternatives consisted only of roadway capacity improvements and modifications:

1. No Action;
2. Transportation System and Transportation Demand Management;
3. Waco Drive Widening;
4. Conversion of one-way pair to two-way operation;
5. Extension of same one-way pair with proper transitions and connections;
6. Extend other arterial and widen to create an alternate route; and,
7. Widen a third arterial to create an alternate route.

All measures except for a benefit-cost analysis were qualitative.

Initial Screening: (measures judged either mostly positive effects, mostly negative effects, or neutral)

- Travel Forecasting
- Engineering Constraints
- Environmental Consequences

Alternatives 3, 4, 5, and 6 were selected for further analysis. TSM/TDM improvements were decided to be implemented along with these alternatives.

Evaluation Criteria:
Transportation Impacts
- Existing and future traffic demand (ADT);
- Travel efficiency (VMT and VHT);
- Impact on Transit;
- Impact on goods movement;

Environmental Consequences
- Social and economic impacts;
- Land use and development impacts;
- Displacement impacts;
- Visual and aesthetic impacts;
- Air quality impact (quantity of delay);

Financial Impacts
- Construction costs; and,
- Available funding.

Findings. The MIS report documentation contained little description of how the preferred alternative was selected. It was suggested that two of the alternatives be combined into the preferred solution and a third alternative be recommended for future implementation as traffic warrants.

The analysis of this MIS is fairly qualitative in nature and did not contain multimodal alternatives. In the end, almost all of the alternatives analyzed were recommended for implementation. This suggests that the MIS was not particularly useful in determining the preferred alternative. Like the Tyler study, this MIS was performed to fulfill federal planning regulations. Public participation was cited as the main benefit of having preformed the MIS.

Description of Measures of Effectiveness

This section summarizes and describes the MOEs that were found in the literature review and the state-of-the-practice review in Texas. The measures fall into five basic categories that relate to the benefits or impacts of a transportation investment:

- Transportation Performance
- Financial/economic Performance
- Social Impacts
- Land Use/Economic Development Impacts
- Environmental Impacts

The specific MOEs are shown in Table 10. The next section provides a discussion of the MOEs in Table 10.

Table 10. Candidate Measures of Effectiveness.

Transportation Performance	Financial/Economic Performance	Social Impacts	Land Use/Economic Development Impacts	Environmental Impacts
• average travel time • total delay • average travel rate • person miles of travel in congestion ranges • person movement • person hours of travel in congestion ranges • person movement speed • accident reduction • average speed • corridor mobility index • average vehicle occupancy • mode split • intermodal or system connectivity/continuity • average delay rate • enforceability • vehicle-miles of travel in congestion ranges • hours of congestion • relative delay rate • delay ratio • average daily traffic • trip time reliability • level of service • lane-mile hours of congestion • volume-to-capacity ratio • queue length	• benefit-to-cost ratio (cost-effectiveness) • financial feasibility • cost per new person-trip • total or "full" costs • user benefits • equity • staged improvement feasibility	• number of displaced persons • number and value of displaced homes • accessibility to community services (e.g., hospital, school, fire, police) • neighborhood cohesion (increased traffic on local streets) • neighborhood quality • construction traffic and disruption • public lands/facilities • recreation benefits	• number and value of displaced businesses • accessibility to employment • accessibility to retail shopping • accessibility to new/planned development sites • tourism benefits	• noise levels (dB) • mobile source emissions/air quality • energy consumption • visual quality/aesthetics • water resources • wetlands/flood plain • wildlife/vegetative habitat • parklands/open/green space • agriculture/forest resources • cultural (historic, archaeological) resources • geological resources • hazardous wastes • vibration

Transportation Performance MOEs

This section describes transportation performance measures for use in a MIS. Additional discussion of many of these measures is contained in References (13) and (14).

The **average travel time** between two points along a corridor can be used to compare alternatives that may only affect that corridor. Average travel times for a trip along several corridors should be used when the effects of transportation improvements extend to areas outside of a single corridor. When different modes are compared, door-to-door travel times are more reflective of the trip length as experienced by users of different lengths. Travel time differences or travel time savings may be applicable for some analyses.

The **average travel rate** is the rate of motion, in minutes per mile, for a corridor segment or vehicle trip. The travel rate is the inverse of speed, and is calculated by dividing the travel time by the trip length. Travel rates are useful in intermediate calculations and analyses. The **average delay rate** is the rate of time loss, in minutes per mile, when operating in congested conditions. The delay rate requires that congestion be defined through the use of an acceptable travel rate. The delay rate can be calculated by taking the difference between the actual travel rate and the acceptable travel rate.

The **relative delay rate** is a dimensionless measure that can be used as a congestion index to compare the relative congestion on facilities, modes, or systems in relation to different mobility standards for system elements such as freeways, arterial streets, or transit routes. The relative delay rate can be calculated by dividing the delay rate by the acceptable travel rate. The **delay ratio** is a dimensionless measure that can be used to compare or combine the relative congestion levels on facilities or systems with different operating characteristics, like freeways, arterial streets, and transit routes. The delay ratio is calculated by dividing the delay rate by the actual travel rate. The delay ratio identifies the magnitude of the mobility problem in relation to actual conditions (as opposed to the relative delay rate which compares system operations to a standard).

Average speed is a measure that relates to all forms of transportation and is understood by non-technical audiences. The **total delay** is the sum of lost time due to congestion, and can be expressed in terms of vehicle-hours, person-hours, or ton-hours. Total delay in a corridor is calculated as the sum of individual vehicle/segment delays. The quantity of delay is commonly used as an estimate of the impact of improvements on transportation systems. Delay is factored into many economic analyses that assign a cost to delay experienced by vehicles, persons, and goods.

Trip time reliability is the range of travel times experienced during a large number of daily trips. For instance, the trip time reliability on uncongested transportation facilities might be between 12 and 15 minutes (range of 3 minutes) on 85 percent of all trips, whereas a trip on congested facilities might be between 20 and 30 minutes (range of 10 minutes) on 85 percent of all trips. Trip time reliability can be expressed as a range in travel times or as a measure of variation, like standard deviation.

Person-miles of travel (PMT) is the product of person volume and roadway segment length. Person volumes for highways are typically estimated by multiplying vehicle volumes by average vehicle occupancies. **Congested PMT** is the person travel that occurs in congested conditions. Congested PMT can also be defined for several congestion ranges, like low, moderate and severe.

The **mode split** describes the percentage of persons using the different transportation modes along a corridor or in a region. For example, the 1990 national average mode split for journey-to-work trips is the following: auto, 91.4%; public transit, 5.5%, other (bicycling, walking, etc.), 3.1% (30).

The **average vehicle occupancy** is the average number of persons in a vehicle, and can include buses and other high-occupancy vehicles. Average vehicle occupancy is usually counted at spot locations or screen lines. This measure can also be estimated if the mode split and total vehicle volumes are known.

Person movement is the number of persons completing all or a portion of a trip, and is typically expressed in persons per hour. In multimodal corridors, person movement is determined by summing person volumes from the individual modes. **Person movement speed** is the product of person movement and average speed, and is expressed in person-miles per hour. High values of person movement speed generally indicate efficient movement of persons (i.e., many persons at high speeds).

The **corridor mobility index** consists of the speed of person movement value divided by some standard value, such as one freeway lane operating at capacity with a typical urban vehicle occupancy rate. This may be one method of addressing the magnitude and relativity problems with the speed of person movement. For instance, a freeway lane operating at high speed and volume might have a volume of 2,100 vehicles per hour at 50 mph. With an occupancy rate of 1.2 persons per vehicle the normalizing value would be approximately 125,000. A similar value can be calculated for an arterial street lane using a capacity of between 1,600 and 1,800 vehicles per hour, 50 to 60 percent green time on the road being analyzed and operating speeds between 20 mph and 25 mph. A normalizing value of approximately 20,000 to 25,000 appears reasonable for arterial streets. The corridor mobility index, therefore, provides a relative value that can be used to compare alternative transportation improvements (e.g., high-occupancy vehicle treatments) to traditional improvements such as additional freeway lanes.

$$Corridor\ Mobility\ Index = \frac{Speed\ of\ Person\ Movement}{Normalizing\ Value\ (e.g.,\ 25{,}000\ or\ 100{,}000)} \qquad \textbf{(1)}$$

Intermodal or system connectivity is a qualitative measure that describes the degree to which different modes (e.g., auto, transit, bicycling, walking) are connected. Connection of different modes are important to provide transportation alternatives for persons that must utilize different modes.

Hours of congestion is the amount of time that transportation facilities operate in congested conditions. Also known as the duration of congestion, this measure requires that congestion levels be defined for many different time periods throughout the day (i.e., morning, noon, and evening peak periods). Twenty-four hour traffic or planning models can be used to estimate daily congestion conditions. For example, many urban areas experience three to four hours of congestion per day on the freeway system.

The measure **lane-mile hours of congestion** refines the duration aspect of congestion by specifying the number of roadway lane-miles on which the congestion takes place. Lane-mile hours requires specific congestion information about specific segments of the roadway system, whereas hours of congestion is non-specific and can be generalized for a corridor or region.

Vehicle-miles of travel (VMT) is simply the product of vehicle volume and roadway segment length. In the past, VMT was used to the quantify vehicular travel demand because vehicle volumes were readily available through data collection or computer modeling programs. **Congested VMT** is the vehicle travel that occurs in congested conditions. Congested VMT can also be defined for several congestion ranges, like low, moderate and severe.

The **average daily traffic (ADT)** volume is the average number of vehicles that traverse a roadway segment during a typical day. If volumes are counted at a location year-round, the result is an annual ADT (AADT). Average weekday traffic (AWT) are also used for some applications.

The **volume-to-capacity (v/c) ratio** is a ratio that divides the vehicle volume by the theoretical roadway capacity. The v/c ratio is typically reported for peak hour traffic operations, and the capacity value is based upon roadway geometric and cross-section features.

Level of service (LOS) is a qualitative letter grade, ranging from "A" for free-flow traffic conditions to "F" for forced flow, that describe the quality of service. The 1994 Highway Capacity Manual (31) defines procedures for measuring and estimating LOS using traffic volumes, speeds, and other traffic data.

Queue length, typically measured in feet or miles, is the length of a standing vehicle queue. Queue length is most often used when evaluating point locations, such as a signalized intersection or a toll plaza. Queue lengths can be measured in the field or estimated using computer models.

Accident reduction is a transportation safety measure that accounts for the reduction in magnitude or severity of vehicle, bicycle, or pedestrian crashes. The accidents or accident reduction can be expressed as the number of accidents, injuries, or fatalities per person-mile of travel.

Enforceability relates to how well the transportation project will operate given reasonable enforcement resources. For instance, some transportation improvements are accompanied by changes in vehicle restrictions or movement that are difficult to enforce, thus jeopardizing the success of the improvement.

Financial/Economic Performance MOEs

This section describes financial/economic performance measures that can be used in a MIS. Cost-effectiveness measures like the b/c ratio are garnering increased attention in current transportation analyses, particularly as they relate to transportation policy. Engineers and planners have joined with economists in an effort to identify and calculate the full costs of transportation to society, including many transportation externalities that haven't been considered in previous cost-effectiveness analyses. In this category of MOEs, the components of the measures are nearly as important as the measures themselves. This section describes several financial/economic performance measures, and presents the major cost and benefit components that are being considered in current full transportation cost studies.

The cost effectiveness, **benefit-to-cost (b/c) ratio** has been used for quite some time to compare the benefits of a transportation project to the costs. The costs have traditionally included only those costs borne by the transportation builder (i.e., state or city department of transportation), and generally include construction and right-of-way acquisition cost. Recent research into full transportation costs has included many externalities of transportation, the cost of which is borne by the general public. Transportation projects are typically considered cost-effective if the b/c ratio exceeds 1.0 (benefits are greater than the costs).

The full costs of transportation can include:

- accidents-human injury/fatality
- accidents-vehicle damage
- aesthetics
- air pollution costs
- automobile waste disposal
- congestion/travel delay
- construction of infrastructure
- court costs
- driver training/education
- external resource consumption
- fuel
- hydrological impacts (drainage)
- incident delay
- insurance
- litter
- middle east oil protection
- noise
- opportunity cost of row
- police/emergency services
- program administration
- property values
- rehabilitation
- roadway maintenance
- right-of-way acquisition
- snow/ice removal
- street lighting
- tolls
- transportation planning efforts
- vehicle operating costs (parking, fuel, maintenance, registration)
- vehicle depreciation
- vibrations
- water pollution

Benefits of transportation projects typically include:

- Reduction in travel time;
- Reduction in emissions;
- Reduction in energy use;
- Increase in mobility; and,
- Increases in land values.

Financial feasibility compares the available funding to the estimated project construction and operating cost, and serves as a reality check for costly alternatives (5). With financial feasibility, the following question is considered: Is it reasonable to assume that there would be sufficient funds available to construct and operate this alternative?

The measure of **equity** describes whether the costs and benefits of the transportation improvement are distributed across different population and demographic groups (5). Equity analyses consider the following questions: Do different population groups benefit from this transportation improvement? Are the costs of constructing and operating this transportation improvement distributed among different population groups? Are the benefits received by a group commensurate with the costs imposed upon that group?

Some transportation agencies are using **staged improvement feasibility** to evaluate whether a transportation project can be sub-divided into several smaller projects, yet still provide benefits when built in stages. This qualitative criteria is often used for large, high-cost projects in urban areas where the transportation improvement program (TIP) must be financially constrained.

The measure **cost per new person-trip** is typically associated with transit improvements, but could be used to associate full costs to an increase in person movement. This measure is considered a cost-effectiveness indicator.

Social Impact MOEs

MOEs for social impact provide information about the effects of transportation projects on persons and their cultures. These MOEs are often more qualitative than performance or cost-effectiveness measures, but nonetheless provide a valuable means for assessing the social impact of transportation projects.

The **number of displaced persons** and the **number of displaced homes** measures the direct impacts of transportation projects. Although displaced persons are compensated for their loss of property and/or homes, the compensation may not cover the sentimental or cultural value.

Neighborhood cohesion describes the effects of through traffic disruption within a neighborhood. Increased traffic on residential streets prompts concerns about safety, noise, and quality-of-life issues. **Neighborhood quality** is a qualitative measure best quantified by neighborhood or community opinion.

Accessibility to community services, like hospital, public transit, school, fire, police, shopping, or service centers, can be used to compare the impacts of different transportation improvements. Accessibility can be expressed in terms of the average time per trip to different community services, or as the percentage of population or households within a certain time limit of community services.

A **net gain/loss of public lands or facilities** estimates the impact of transportation projects on public parks, forests, green space, or other public lands that are used or enjoyed by residential communities. Also related to public lands or facilities is the **recreation benefits** that may be associated to a transportation improvement.

Construction traffic and disruption is a qualitative measure that estimates the range of disruption to communities from construction of transportation projects.

Land Use/Economic Development Impact MOEs

This category of MOEs estimates the interrelationship of land use and economic development impacts of transportation projects. Some of the measures in this category are quantitative and require detailed analyses, whereas others are more qualitative.

The **number of displaced businesses** can affect the economic vitality of commercial areas near transportation projects.

Accessibility has been defined as "a measure of the ability or ease of all people to travel among various origins and destinations" (32). Accessibility measures the interactions between transportation and land use, and how well transportation facilities connect various land uses. Recent research on congestion measures added a time element to accessibility, and defined it as "the achievement of travel objectives within time limits regarded as acceptable" (33).

Accessibility of residential housing to the transportation improvement could be expressed as the population or number of person trips with "X" minutes of the facility or system access, where "X" minutes is related to regional or local transportation policy and goals. **Accessibility of commercial land use/jobs** to the transportation improvement could be expressed as the number of jobs within "X" minutes of the facility or system access. **Accessibility to future development sites** can be calculated as the number of sites to be developed within "X" minutes of the transportation project.

Tourism benefits are often measured in terms of increased revenue or economic productivity. Many benefits of tourism are related to easy, convenient access to sights or attractions.

Environmental Impact MOEs

MOEs that relate to environmental impact are often considered in the environmental assessment/environmental impact statement (EA/EIS) portion of a MIS. The level of detail for several of the measures are consistent with the detail provided in an Option II MIS, whereas more-detailed measures may be difficult to quantify for an Option I MIS (where the EIS is not part of the alternatives analysis).

Mobile source emissions analyses quantify the increase or decrease in emissions caused by auto, trucks, buses, trains, and other transportation modes being considered. Mobile source emissions quantities typically considered in transportation analyses include **carbon monoxide (CO)**, **hydrocarbons (HC)**, **nitrous oxides (NO_X)**, and **particulate matter (PM-10)**. Emissions analyses are required for all non-attainment areas as designated by the Clean Air Act Amendments of 1990.

Noise levels, measured in decibels (dB), is also considered an environmental impact, and has been the impetus behind noise walls constructed along many major urban freeways. **Vibration** from automobiles, buses, trains, and other vehicles are also considered in many environmental assessments.

Energy or fuel consumption measures the amount of energy required to perpetuate or operate the transportation improvement. For automobiles and buses, fuel or diesel fuel would be considered, and for light and heavy rail transit, electricity would be considered.

There are several environmental impacts that relate to the transportation improvement's impact on various land types or resources. The **impact on water resources**, including surface water, ground water, wetlands, and floodplain, should be evaluated in terms of reduction, degradation of quality or depletion. The **impact on wildlife and vegetative habitat** is also a consideration, particularly where threatened or endangered species are present. The **impact on parklands, open, or green spaces** is a concern, particularly for dense urban areas wishing to conserve their existing green/open space. The **impact on agriculture or forest resources** will be a concern with transportation and development on the fringe of an urban area. The **impact on geological resources** is also a concern with environmental assessments.

Cultural resources, like **historic or archaeological resources**, are important for community character and identity. **Hazardous wastes**, like **chemical and solid wastes**, pose potential public health and safety problems, and should be considered in the environmental assessment.

Visual or aesthetic quality, like neighborhood quality, is a qualitative measure that is best determined by the affected community.

Qualitative Assessment of Measures of Effectiveness (MOEs)

The research team performed a qualitative assessment of the measures summarized in Table 10 and described in the previous section. To evaluate the MOEs, a list of desirable measure criteria was developed. The MOEs were then compared to this criteria, and a ranking score was given to each MOE based on its ability to meet these five criteria:

Applicability to Individual and Aggregate Transportation Modes
- Does the measure apply to both individual modes and/or aggregation of transportation modes?
- Is the measure strongly related to a specific mode?

Ease of Measure Calculation and Analyses
- Is calculation of the measure difficult?
- Can the measure be calculated/calibrated with existing field data?
- Are there techniques available to estimate the measure?
- Are data or information for the estimation techniques readily available?
- Are the measure results easy to analyze?

Accuracy of Measure Results
- Is the accuracy level of the estimation techniques acceptable?
- Is the measure sensitive to small changes in assumptions or base case conditions?
- Are the precision of the measure results consistent with a planning-level analyses?

Clear and Consistent Interpretation of Results
- Do the measure results clearly and directly reflect the impact of certain transportation alternatives?
- Are the measure results able to be clearly interpreted?
- Is there ambiguity in the measure results?
- Does the measure have professional credibility?

Clarity and Simplicity
- Are the measure units well-defined and quantifiable?
- Is the measure understood by technical and non-technical audiences?

The research team's qualitative assessment of the MOEs is contained in the Appendix, with short evaluations of each measure provided for each criteria. For each of the above five criteria, the MOEs wre given a numerical score ranging from +1.0 to -1.0 as follows:
- +1.0: Measure ideally suited to criteria requirements.
- +0.5: Measure meets basic requirements of criteria.
- 0.0: Questionable application of measure based upon criteria.
- -0.5: Measure does not meet basic requirements of criteria; and,
- -1.0: Measure negatively impacts evaluation process.

The numerical scores were summed for a total score, which was used as the basis for the qualitative evaluation. From the qualitative evaluation and the MIS state-of-the-practice review in Texas, the measures in Table 11 are preferred for evaluating the impacts of transportation projects within a MIS analysis framework. The measures in Table 11 are preferred because of their clarity, utility, and applicability to a wide range of transportation modes and alternatives. Other MOEs in Table 10 but not in Table 11 may be more applicable or relevant for certain analyses where the multimodal or intermodal alternatives are not being considered, or where the context of the analysis requires specific measures.

The preferred transportation performance MOEs are predominantly related to persons and time. The focus on persons and time matches the focus of transportation engineering, which is the " . . . safe and efficient movement of people and goods." These person movement and time-related measures quantify the impacts and effectiveness of a wide range of transportation alternatives.

The preferred MOEs for estimating the financial/economic performance are the benefit-to-cost (b/c) ratio (using the "full" or total transportation costs), financial feasibility, and equity. Total cost analyses used to generate these measures account for transportation externalities and other costs that typically are not payed directly for the construction of a transportation improvement.

The preferred MOEs for assessing the social impact of transportation projects include the number of displaced persons and homes, neighborhood cohesion (traffic through neighborhoods), and the accessibility to community services. These measures are primarily quantitative, and the values represent actual calculated numbers. Public or community perception may be used as a qualitative measure of a project's social impact.

The preferred MOEs for the land use/economic development impact are the number of displaced businesses and the accessibility to employment and future development sites. These measures assess the relation of the proposed transportation project to current and projected land uses in the corridor.

The preferred MOEs for assessing the environmental impacts include energy/fuel consumption, mobile source emissions, noise levels, and visual/aesthetic quality. These measures could be used in either an Option I or Option II MIS (see Figure 2). Impacts that must be considered in an Option II MIS, where an EIS is part of the MIS process, include vibration, water resources, wildlife/vegetative habitat, parkland/open/green space, cultural resources, agriculture/forest resources, geologic resources, and hazardous wastes. The assessment of these impacts requires substantial resources, and would most likely not be considered in an Option I MIS, in which the EIS is performed on the locally preferred alternative. The question of whether an Option I MIS meets federal environmental requirements is still an issue of concern for many transportation agencies.

Table 11. Preferred Measures for Evaluating the Performance and Impact of Transportation Improvements

Transportation Performance • average travel time • total delay (vehicle, person or ton-hours) • average travel rate • person-miles of travel (PMT), or PMT in congested ranges • person movement • person-hours of travel (PHT), or PHT in congested ranges • person movement speed • accident reduction
Financial/Economic Performance • benefit-to-cost ratio (using total or full cost analysis) • financial feasibility • cost per new person-trip
Social Impacts • number of displaced persons • number and value of displaced homes • accessibility to community services • neighborhood cohesion
Land Use/Economic Development Impacts • number and value of displaced businesses • accessibility to employment • accessibility to retail shopping • accessibility to new/planned development sites
Environmental Impacts • noise levels (dB) • mobile source emissions (NO_x, HC, CO, and PM-10) • energy consumption • visual quality/aesthetics • water resources (Option II MIS only) • wildlife/vegetative habitat (Option II MIS only) • parkland/open/green space (Option II MIS only) • agriculture/forest resources (Option II MIS only) • cultural resources (Option II MIS only) • geologic resources (Option II MIS only) • hazardous wastes (Option II MIS only) • vibration (Option II MIS only)

Selecting Measures of Effectiveness for a Major Investment Study

The evaluation measures and criteria play a critical role in the selection of a locally preferred alternative. The preferred MOEs listed in Table 11 are considered to be the ideal measures for comparing alternatives in a multimodal transportation analysis. All of these MOEs do not necessarily need to be included in a MIS, nor must the MOEs for a MIS come solely from Table 11. Other measures besides those in Tables 10 or 11 may be applicable or appropriate for local conditions or alternatives. When selecting MOEs for the conduct of a MIS, the following should be given due consideration:

- **Match the MOEs with the goals and objectives of the MIS**, which are established at the start of the study. For example, if the MIS is being performed for a freight corridor, consider using freight quantities for transportation performance measures. If the goals of the MIS are to create a greenbelt corridor with linear parks and multi-use paths, select and weight the recreation and environmental impact MOEs.

- **Develop and select the MOEs early in the study with key input from local decision-makers** (5). With buy-in from decision-makers at the start, study conclusions are less likely to be questioned. This practice also promotes a sense of fairness and teamwork among cooperating agencies.

- **Use a comprehensive set of measures, but do not substantially duplicate or restate benefits or impacts** (5). Many of the cost-effectiveness MOEs are derived from transportation performance or other impacts, but provide a different perspective on the magnitude or impact.

- **When possible, quantify impacts and don’t simply use subjective judgment** (5). Many of the preferred MOEs in Table 11 are quantitative and can be calculated or estimated using standard procedures. Other MOEs are clearly subjective, and should be presented as such.

- **Provide perspective on the magnitude of the impacts** (5). Make an interpretation of the MOE values and their significance on a sub-area or regional basis. Although some MOE values may seem large, their overall significance in the urban area may be small.

- **Identify the error levels of calculations in relation to the measure values** (5). Provide perspective when measure values have been estimated or modeled using computer programs. Consider whether differences in measure values between alternatives could be due to estimation error.

This page intentionally left blank.

CHAPTER IV. CONCLUSIONS AND RECOMMENDATIONS

This chapter summarizes the conclusions and recommendations of this study, which was focused on identifying measures of effectiveness (MOEs) for major investment studies.

Conclusions

The selection of MOEs is a critical element of the major investment study. The measures selected to evaluate alternative transportation improvements determine what information is provided to decision-makers and seriously affects the conclusions of the study. Smaller MISs investigated in this study often did not include a sufficient range of MOEs, leading to decisions based on incomplete evidence. With full information provided by a complete range of MOEs, a completely informed decision can be incorporated into a MIS.

Table 11 lists MOEs that are ideally suited to multimodal transportation analyses. The designation of "preferred MOEs" in this table reflects the results of a qualitative assessment and state-of-the-practice review of MISs in Texas. Transportation performance measures that were most frequently cited in the literature and state-of-the-practice reviews include time- and person-based measures. Both are relatively easy to calculate with field observations or to estimate with computer models. Vehicle-based MOEs are often easier to calculate and estimate, but have modal biases which are corrected with the use of person-based MOEs.

The economic, social, land use, and environmental impacts of transportation improvements can not be ignored. These issues are often complicated and their impacts can be difficult to quantify. The importance of providing as much information regarding these impacts as possible should be tempered by the cost of quantifying these impacts. The MOEs cited in Table 11 are easily quantifiable and cover a range of impacts that is sufficient for most MISs. However, it is important to realize that individual MISs may have different considerations, and impacts not quantified by the MOEs in Table 11 may need to be highlighted in the analysis.

Recommendations

Selection of MOEs for inclusion in a MIS should be undertaken very carefully. The MOEs need to blend the concerns of the technical practitioners with those of the general public. Generally, those performing a MIS are more concerned with the effects on the transportation system and the costs of the improvement project, while the general public is also interested in the social and environmental impacts of alternatives. The needs of both must be addressed. It is recommended that a wide range of both technical MOEs and social/environmental MOEs be selected to address the concerns of all participants.

The MOEs recommended in Table 11 are not meant to serve as a "cookbook" for all major investment studies. Each MIS will be unique. Different corridors in different cities may have differing concerns which need to be addressed. A MIS in Galveston would require the consideration of effects on wetlands and storm water management. These considerations, however, might be unimportant in El Paso. This research is meant to serve as a guide, presenting a base of MOEs which would be useful in almost any MIS. Concerns of individual cities and corridors should be included, and MOEs measuring impacts related to these concerns developed and included in a MIS.

REFERENCES

1. Federal Register, Part II, Department of Transportation, Federal Highway Administration, Federal Transit Administration, 23 CFR Part 450 and 49 CFR Part 613, October 28, 1993.

2. "Major Investment Studies: Questions and Answers," Federal Highway Administration/Federal Transit Administration, September 1994.

3. "Training Program for Major Investment Studies: Course Manual," Prepared by National Transit Institute and Parson Brinckerhoff Quade & Douglas, Inc., 1995.

4. Elders, Sheldon. CMS and MIS: A Reciprocal Relationship. *ITE Journal: Congestion Management News*, Institute of Transportation Engineers, Washington, D.C., May 1995.

5. National Transit Institute. *Desk Reference: Training Program for Major Investment Studies.* Draft. U.S. Department of Transportation, Washington, D.C., April 1996.

6. Hess, K.J. and L.E. Pesesky. Integrating Major Metropolitan Transportation Investment Study Process with National Environmental Policy Act Process. In *Transportation Research Record 1475*, TRB, National Research Council, Washington D.C., 1995.

7. Cohen, H.S., J.R. Stowers, and M.P. Petersilia. *Evaluating Urban Transportation System Alternatives*. Report No. DOT-P-30-78-44. U.S. Department of Transportation, Washington, D.C., 1978.

8. Abrams, C.M. and J.F. DiRenzo. *Measures of Effectiveness for Multimodal Urban Traffic Management, Volume 2: Development and Evaluation of TSM Strategies*. Report No. FHWA-RD-79-113. FHWA, U.S. Department of Transportation, Washington, D.C., 1979.

9. Stuart, D.G. and W.D. Weber. Accommodating Multiple Alternatives in Transportation Planning. In *Transportation Research Record 639*, TRB, National Research Council, Washington, D.C., 1977, pp. 7-13.

10. Walbridge, E.W. Selection of Urban Transportation Systems. *Transportation Planning and Technology*. Vol. 6, Gordon and Breach Science Publishers, Inc., London, 1981, pp. 221-231.

11. Rutherford, G.S. *Synthesis of Highway Practice 201, Multimodal Evaluation of Passenger Transportation*. National Cooperative Highway Research Program, National Academy Press, Washington, D.C., 1994.

12. Cambridge Systematics, Inc. "Task B--Initial Performance Measures," In *Metropolitan Planning Technical Report*. Report No. 2. Federal Highway Administration, Washington, D.C., July 1994.

13. Lomax, T.J., S.M. Turner, G. Shunk, H.S. Levinson, R.H. Pratt, P.N. Bay, G.B. Douglas. *Quantifying Congestion: Final Report*. National Cooperative Highway Research Program, Washington, D.C., September 1996.

14. Lomax, T.J., S.M. Turner, G. Shunk, H.S. Levinson, R.H. Pratt, P.N. Bay, G.B. Douglas. *Quantifying Congestion: User's Guide*. National Cooperative Highway Research Program, Washington, D.C., September 1996.

15. Meyer, M.D. *Alternative Performance Measures for Transportation Planning: Evolution Toward Multimodal Planning*. Report No. FTA-GA-26-7000-95-1. Georgia Institute of Technology, Atlanta, Georgia, December 1995.

16. Ewing, R. Measuring Transportation Performance. Transportation Quarterly, Vol. 49, No. 1, Eno Transportation Foundation, Lansdowne, Virginia, Winter 1995.

17. "Intermodal Connections," Insert to the *ITE Journal*, Institute of Transportation Engineers, August 1995.

18. "Intermodal Connections," Insert to the *ITE Journal*, Institute of Transportation Engineers, October 1995.

19. "Intermodal Connections," Insert to the *ITE Journal*, Institute of Transportation Engineers, December 1995.

20. Frye, F. F. *Alternative Multimodal Passenger Transportation Systems: Comparative Economic Analysis*. NCHRP Report 146. National Cooperative Highway Research Program, Washington D.C., 1973.

21. Rahman, W. M. and K.B. Davidson. A Model for the Analysis and Evaluation of Urban Transport. *Proceedings*, Australia Road Research Board, 1968.

22. Freeman, J. and B. Hutchinson. Investment Evaluation Model for Multimodal Transport Corridors. In *Transportation Research Record 550*, TRB, National Research Council, Washington D.C., 1975.

23. DeCorla-Souza, P. and R. Jensen-Fisher. Comparing Multimodal Alternatives in Major Travel Corridors. In *Transportation Research Record 1429*, TRB, National Research Council, Washington, D.C., 1994.

24. DeCorla-Souza, P. A Least Cost Approach to Compare IVHS, Land Use, Management, and Multimodal Infrastructure Alternatives. *National Conference on Intelligent Transportation Systems and the Environment, Conference Papers*, U.S. Department of Transportation, Arlington, Virginia, 1994.

25. DeCorla-Souza, P. Sketch Planning Analysis Spreadsheet Model User's Guide. A Supplement to NHI Course No. 15257 *Estimation the Impacts of Urban Transportation Alternatives*, National Highway Institute, Washington, D.C., 1996.

26. Qin, Weissmann, Euritt, and Martello. Evaluating Full Costs of Urban Passenger Transportation. Paper presented at the 75th Annual Meeting of the Transportation Research Board, National Research Council, Washington, D.C., 1996.

27. Litman, T. *Transportation Cost Analysis: Techniques, Estimates and Implication*. Victoria Transport Policy Institute, Victoria, BC, 1996.

28. "MIS Case Studies: Examples of Major Investment Studies in Transportation," FHWA, FTA, and U.S. Department of Transportation, Distributed at the Transportation Research Board's Conference on Major Investment Studies, San Francisco, CA, 1996.

29. HNTB, Inc. "IH-435 Major Investment Study," located on the World Wide Web,: "http://www.hntb.com/mhtd/i435mis.html".

30. Hu. P.S. and J. Young. *Summary of Travel Trends: 1990 Nationwide Personal Transportation Survey*. Report FHWA-PL-92-027. FHWA, U.S. Department of Transportation, Washington, D.C., March 1992.

31. Transportation Research Board Special Report 205, *1994 Highway Capacity Manual*, National Research Council, Washington, D.C., 1994.

32. Gray, B.H. Ed. *Urban Public Transportation Glossary*. Transportation Research Board, Washington, D.C., 1989.

33. Ewing, R. *A Unified Set of Transportation Performance Measures*. Florida Atlantic University, n.d.

This page intentionally left blank.

APPENDIX

Qualitative Assessment of

Measures of Effectiveness for

Major Investment Studies

This page intentionally left blank.

Table A-1. Qualitative Assessment of Measures of Effectiveness for Major Investment Studies

Measure of Effectiveness	Applicability to Modes	Ease of Calculation and Analyses	Accuracy of Results	Clear and Consistent Interpretation	Clarity and Simplicity	Total Score
Transportation Performance						
average travel time	1.0 Ideal for multimodal comparisons	1.0 Relatively easy to estimate/measure	1.0 Suitable for technical analyses	0.5 Interpretation may vary	1.0 Understood by non-technical audiences	**4.5**
total delay (vehicle-hour, person-hours, ton-hours)	1.0 Ideal for multimodal comparisons	1.0 Easily estimated using model	0.5 Ideal for corridor analyses	1.0 Clear, widespread credibility	1.0 Understood by most audiences	**4.5**
average travel rate	1.0 Ideal for multimodal comparisons	1.0 Relatively easy to estimate/measure	1.0 Suitable for technical analyses	0.5 Interpretation may vary	0.5 Measure units not understood by some	**4.0**
person-miles of travel (PMT) or PMT in congestion ranges	1.0 Ideal for multimodal comparisons	0.5 Based on vehicle occupancy	0.5 Meets basic requirements	1.0 Clear interpretation	1.0 Most suitable for technical audience	**4.0**
person movement (persons per hour)	1.0 Ideal for multimodal comparisons	0.5 Based on vehicle occupancy	0.5 Acceptable	1.0 Interpretation varies	1.0 Understood by non-technical audience	**4.0**
person-hours of travel (PHT) or PHT in congestion ranges	1.0 Ideal for multimodal comparisons	0.5 Based on vehicle occupancy	0.5 Meets basic requirements	0.5 Interpretation sketchy	1.0 Most suitable for technical audience	**3.5**
person movement speed (person-mph)	1.0 Ideal for multimodal comparisons	0.5 Simple calculations, based on occupancy	0.5 Acceptable	1.0 Comparative measure values	0.5 Geared for technical audience	**3.5**

Ratings: 1.0=ideally suited; 0.5=meets basic requirements; 0.0=questionable application; -0.5=does not meet basic requirements; -1.0=negatively impacts evaluation.
NOTE: Shaded rows represent "preferred measures."

Table A-1. Qualitative Assessment of Measures of Effectiveness for Major Investment Studies (Cont.)

Measure of Effectiveness	**Applicability to Modes**	**Ease of Calculation and Analyses**	**Accuracy of Results**	**Clear and Consistent Interpretation**	**Clarity and Simplicity**	**Total Score**
accident reduction	0.5 Suitable for all modes	0.5 Sometimes difficult to estimate	0.5 Sensitive to many other factors	1.0 Clear interpretation	1.0 Easy for public to relate to	**3.5**
average speed	0.5 Suitable for some comparisons	1.0 Relatively easy to estimate	0.5 Suitable for some technical analyses	0.5 Interpretation varies	1.0 Understood by most audiences	**3.5**
corridor mobility index	1.0 Ideal for multimodal comparisons	1.0 Requires normalization	0.5 Acceptable	0.5 Consistent interpretation?	0.5 Geared for technical audience	**3.5**
average vehicle occupancy	1.0 Suitable for comparisons	0.5 Difficult to estimate/measure	0.5 Varies by technique	1.0 Interpretation varies	0.5 Suitable	**3.5**
mode split	1.0 Suitable for comparisons	1.0 Relatively easy to estimate	0.0 Sensitive to many factors	0.5 Clear interpretation	0.5 Values easy to understand	**3.0**
intermodal or system connectivity	1.0 Ideal for modal analyses	0.5 Qualitative analysis	0.0 Consistent with planning analyses	0.5 Subjective measure	0.5 Suitable	**2.5**
average delay rate	0.5 Ideal for multimodal comparisons	0.5 Requires definition of standards	0.5 Sensitive to standards	0.5 Interpretation may vary	0.5 Measure units not understood by some	**2.5**
enforceability	0.0 Questionable for some modes	0.5 Qualitative analysis	0.5 Suitable for planning analysis	0.5 Subjective in nature	0.5 Aimed at technical audience	**2.0**

Ratings: 1.0=ideally suited; 0.5=meets basic requirements; 0.0=questionable application; -0.5=does not meet basic requirements; -1.0=negatively impacts evaluation.
NOTE: Shaded rows represent “preferred measures.”

Table A-1. Qualitative Assessment of Measures of Effectiveness for Major Investment Studies (Cont.)

Measure of Effectiveness	Applicability to Modes	Ease of Calculation and Analyses	Accuracy of Results	Clear and Consistent Interpretation	Clarity and Simplicity	Total Score
vehicle-miles of travel (VMT) or VMT in congestion ranges	-0.5 Only applicable for roadway	1.0 Relatively easy to estimate	0.5 Varies	0.5 Has credibility	0.5 Suitable for technical audience	**2.0**
hours of congestion	0.5 Suitable for some comparisons	0.5 Somewhat difficult to estimate	0.0 Varies, questionable	0.0 No definition of severity	0.5 Easy for public to relate to	**1.5**
relative delay rate	0.5 Suitable for some comparisons	0.5 Requires definition of standards	0.5 Sensitive to standards	0.0 Difficult to interpret	0.0 Measure values not understood	**1.5**
delay ratio	0.5 Suitable for some comparisons	0.5 Requires definition of standards	0.5 Suitable for technical analyses	0.0 Difficult to interpret	0.0 Measure values not understood	**1.5**
average daily traffic (ADT)	-0.5 Only applicable for roadway	1.0 Relatively easy to estimate	0.5 Varies	0.0 Lacks length component	0.5 Understood by most audiences	**1.5**
trip time reliability	0.5 Suitable for some comparisons	0.0 Difficult to estimate	0.0 Estimation accuracy questionable	0.0 Questionable	0.5 Fairly clear, simple	**1.0**
level of service (LOS)	-0.5 Non-uniform comparison	0.0 Not geared to planning level	0.5 Varies by analysis type	0.5 Boundary values problematic	0.5 Understood by most audiences	**1.0**
lane-mile hours of congestion	-0.5 Only applicable for roadway	0.0 Difficult to measure or estimate	0.0 Varies, questionable	0.0 No definition of severity	0.5 Suitable for technical audience	**0.0**

Ratings: 1.0=ideally suited; 0.5=meets basic requirements; 0.0=questionable application; -0.5=does not meet basic requirements; -1.0=negatively impacts evaluation.
NOTE: Shaded rows represent “preferred measures.”

Table A-1. Qualitative Assessment of Measures of Effectiveness for Major Investment Studies (Cont.)

Measure of Effectiveness	Applicability to Modes	Ease of Calculation and Analyses	Accuracy of Results	Clear and Consistent Interpretation	Clarity and Simplicity	Total Score
volume-to-capacity (v/c) ratio	-0.5 Not applicable to all modes	0.0 Estimation of capacity troublesome	0.5 Varies	0.0 Capacity values confound interpret.	0.0 Difficult for non-technical audience	**0.0**
queue length	-0.5 Not applicable to all modes	0.0 Difficult to estimate	0.0 Accuracy varies	0.0 Questionable	0.5 Suitable for technical audience	**0.0**
Financial/Economic Performance						
benefit-to-cost (b/c) ratio	1.0 Ideal for multimodal comparisons	0.5 Range of detail for cost analysis	0.5 Varies by detail of cost analysis	1.0 Demonstrates cost-effectiveness	1.0 Understood by most audiences	**4.0**
financial feasibility	1.0 Ideal for multimodal comparisons	0.5 Requires detailed economic analysis	0.5 Varies by detail of cost analysis	1.0 Reality check for spending	1.0 Understood by most audiences	**4.0**
cost per new person trip	1.0 Ideal for multimodal comparisons	0.5 Range of detail for cost analysis	0.5 Varies by detail of cost analysis	0.5 Comparable to transit subsidies	0.5 Suitable for technical audience	**3.0**
total or “full” costs	0.5 Suitable for comparisons	0.5 Range of detail for cost analysis	0.5 Varies by detail of cost analysis	0.5 Some costs difficult to justify/interpret	1.0 Understood by most audiences	**3.0**
user benefits	0.5 Suitable for comparisons	0.5 Range of detail for benefits analysis	0.5 Varies by detail of cost analysis	0.5 Some benefits difficult to justify	1.0 Understood by most audiences	**3.0**

Ratings: 1.0=ideally suited; 0.5=meets basic requirements; 0.0=questionable application; -0.5=does not meet basic requirements; -1.0=negatively impacts evaluation.
NOTE: Shaded rows represent “preferred measures.”

Table A-1. Qualitative Assessment of Measures of Effectiveness for Major Investment Studies (Cont.)

Measure of Effectiveness	Applicability to Modes	Ease of Calculation and Analyses	Accuracy of Results	Clear and Consistent Interpretation	Clarity and Simplicity	Total Score
equity	1.0 Ideal for multimodal comparisons	0.0 Requires detailed socioeconomic	0.5 Varies by detail of cost analysis	0.5 Requires subjective interpretation	0.5 Somewhat difficult to quantify	**2.5**
staged improvement feasibility	0.5 May favor particular mode	0.5 Qualitative analysis	0.0 Depends upon many other factors	0.5 Requires subjective interpretation	0.5 Requires long-term considerations	**2.0**
Social Impacts						
number of displaced persons	1.0 Ideal for multimodal comparisons	0.5 Detail more suitable for design	0.5 Acceptable for planning analyses	0.5 Duplicates measure of displaced homes	1.0 Easy for public to relate to	**3.5**
number and value of displaced homes	1.0 Ideal for multimodal comparisons	0.5 Detail more suitable for design	0.5 Acceptable for planning analyses	0.5 Suitable	1.0 Easy for public to relate to	**3.5**
accessibility to community services	1.0 Ideal for multimodal comparisons	0.5 Qualitative and quantitative	0.5 Suitable for planning analysis	0.5 Must define services	0.5 Varies, suitable for technical audience	**3.0**
neighborhood cohesion	1.0 Ideal for multimodal comparisons	0.5 Qualitative and quantitative	0.5 Varies	0.5 Somewhat subjective in nature	0.5 Public can relate	**3.0**
neighborhood quality	1.0 Ideal for multimodal comparisons	0.5 Qualitative analysis	0.0 Visualization sometimes difficult	0.5 Subjective interpretation	0.5 Public can relate	**2.5**

Ratings: 1.0=ideally suited; 0.5=meets basic requirements; 0.0=questionable application; -0.5=does not meet basic requirements; -1.0=negatively impacts evaluation.
NOTE: Shaded rows represent "preferred measures."

Table A-1. Qualitative Assessment of Measures of Effectiveness for Major Investment Studies (Cont.)

Measure of Effectiveness	Applicability to Modes	Ease of Calculation and Analyses	Accuracy of Results	Clear and Consistent Interpretation	Clarity and Simplicity	Total Score
construction traffic and disruption	0.5 Suitable for comparisons	0.5 Qualitative and quantitative	0.5 Varies	0.5 Somewhat subjective	0.5 public can relate	**2.5**
impact on public lands/facilities	0.5 Suitable for comparisons	0.5 Relatively easy to quantify	0.5 Acceptable accuracy	0.5 Interpretation varies	0.5 Public can relate	**2.5**
recreation benefits	0.0 No clear connection to modes	0.0 Qualitative analysis	0.0 Questionable	0.5 Subjective in nature	0.5 Best stated in qualitative terms	**1.0**
Land Use/Economic Development Impacts						
number and value of displaced businesses	1.0 Ideal for multimodal comparisons	0.5 Detail more suitable for design	0.5 Varies	1.0 May not include devalued businesses	1.0 Understood by most audiences	**4.0**
accessibility to employment	1.0 Ideal for multimodal comparisons	0.5 Qualitative and quantitative analysis	0.5 Suitable for planning analysis	0.5 Critical for job/housing balance	0.5 Varies, for technical audience	**3.0**
accessibility to retail shopping	1.0 Ideal for multimodal comparisons	0.5 Qualitative and quantitative analysis	0.5 Suitable for planning analysis	0.5 Suitable	0.5 Varies, for technical audience	**3.0**
accessibility to new/planned development sites	1.0 Ideal for multimodal comparisons	0.5 Qualitative and quantitative analysis	0.5 Suitable for planning analysis	0.5 Suitable	0.5 Varies, for technical audience	**3.0**

Ratings: 1.0=ideally suited; 0.5=meets basic requirements; 0.0=questionable application; -0.5=does not meet basic requirements; -1.0=negatively impacts evaluation.
NOTE: Shaded rows represent "preferred measures."

Table A-1. Qualitative Assessment of Measures of Effectiveness for Major Investment Studies (Cont.)

Measure of Effectiveness	Applicability to Modes	Ease of Calculation and Analyses	Accuracy of Results	Clear and Consistent Interpretation	Clarity and Simplicity	Total Score
tourism benefits	0.5 Suitable for comparisons	0.0 Assessment of benefits difficult	0.0 Questionable	0.5 Some benefits qualitative	0.5 Benefits best described in dollars	**1.5**
Environmental Impacts						
noise levels (dB)	1.0 Ideal for multimodal comparisons	0.5 Relatively easy with computer model	0.5 Suitable for planning analyses	0.5 Comparative measure values	1.0 Easy for public to relate to	**3.5**
mobile source emissions (NO_x, HC, PM-10, CO^2)	1.0 Ideal for multimodal comparisons	0.5 Requires extensive modeling	0.5 Questionable by some	0.5 Legally required in TMA's	0.5 Geared for technical audience	**3.0**
energy consumption	1.0 Ideal for multimodal comparisons	0.5 Numerous computer models available	0.5 Suitable for planning analyses	0.5 International applicability	0.5 Understood by most audiences	**3.0**
visual quality/aesthetics	1.0 Ideal for multimodal comparisons	0.5 Based upon public input	0.0 Visualization sometimes difficult	0.5 Subjective measure	0.5 Easy for public to relate to	**2.5**
water resources	0.5 Meets basic requirements	0.5 Requires environ. expertise	0.5 Acceptable within discipline	0.5 Qualitative interpr. necessary	0.5 Suitable for specific audiences	**2.5**
wetlands/flood plain	0.5 Meets basic requirements	0.5 Requires environ. expertise	0.5 Acceptable within discipline	0.5 Qualitative interpr. necessary	0.5 Suitable for specific audiences	**2.5**

Ratings: 1.0=ideally suited; 0.5=meets basic requirements; 0.0=questionable application; -0.5=does not meet basic requirements; -1.0=negatively impacts evaluation.
NOTE: Shaded rows represent "preferred measures."

Table A-1. Qualitative Assessment of Measures of Effectiveness for Major Investment Studies (Cont.)

Measure of Effectiveness	Applicability to Modes	Ease of Calculation and Analyses	Accuracy of Results	Clear and Consistent Interpretation	Clarity and Simplicity	Total Score
wildlife/vegetative habitat	0.5 Meets basic requirements	0.5 Requires environ. expertise	0.5 Acceptable within discipline	0.5 Qualitative interpr. necessary	0.5 Suitable for specific audiences	**2.5**
parklands/open/green space	0.5 Meets basic requirements	0.5 Relatively easy to quantify	0.5 Acceptable within discipline	0.5 Qualitative interpr. necessary	0.5 Suitable for specific audiences	**2.5**
agriculture/forest resources	0.5 Meets basic requirements	0.5 Relatively easy to quantify	0.5 Acceptable within discipline	0.5 Qualitative interpr. necessary	0.5 Suitable for specific audiences	**2.5**
cultural resources	0.5 Meets basic requirements	0.5 Requires specific expertise	0.5 Acceptable within discipline	0.5 Qualitative interpr. necessary	0.5 Suitable for specific audiences	**2.5**
geological resources	0.5 Meets basic requirements	0.5 Requires specific expertise	0.5 Acceptable within discipline	0.5 Qualitative interpr. necessary	0.5 Suitable for specific audiences	**2.5**
hazardous wastes	0.5 Meets basic requirements	0.5 Requires specific expertise	0.5 Acceptable within discipline	0.5 Qualitative interpr. necessary	0.5 Suitable for specific audiences	**2.5**
vibration	0.5 Oriented toward transit	0.5 Requires sophisticated models	0.5 Meets EIS requirements	0.0 Comparative measures values	0.5 Geared to technical audience	**2.0**

Ratings: 1.0=ideally suited; 0.5=meets basic requirements; 0.0=questionable application; -0.5=does not meet basic requirements; -1.0=negatively impacts evaluation.

Ratings: 1.0=ideally suited; 0.5=meets basic requirements; 0.0=questionable application; -0.5=does not meet basic requirements; -1.0=negatively impacts evaluation.
NOTE: Shaded rows represent “preferred measures.”